1946

An analysis of man power efficiency in drilling procedures in the Tri-State Mining District

Julian Alban Fuller

AN ANALYSIS OF MAN POWER EFFICIENCY IN DRILLING PROCEDURES

IN THE

TRI-STATE MINING DISTRICT

BY

JULIAN A. FULLER

****

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

Degree of

MASTER OF SCIENCE

IN

MINING ENGINEERING

Rolla, Missouri

May, 1946

****

Approved by J. D. Forrester
Professor of Mining Engineering

Acknowledgments

The writer wishes to express his appreciation to Dr. J.D. Forrester, Chairman of the Department of Mining Engineering, for suggesting the problem and for his invaluable aid and guidance throughout this investigation.

The author is also greatly indebted to Mr. S. S. Clarke, General Superintendent of Mines, Eagle-Picher Mining & Smelting Company, Cardin, Oklahoma, who so kindly made available his time and much information during the investigation.

The various mines visited offered every facility for obtaining the necessary data. The author wishes to express his thanks to both Mr. A. S. Malocsay and Mr. F. J. Cuddebach of the Paxson and Leapod Mines, respectively.

Preface

This thesis embodies the results of an investigation, by the time study method, of certain phases of drilling procedures recently brought into practice in the Tri-State mining district.

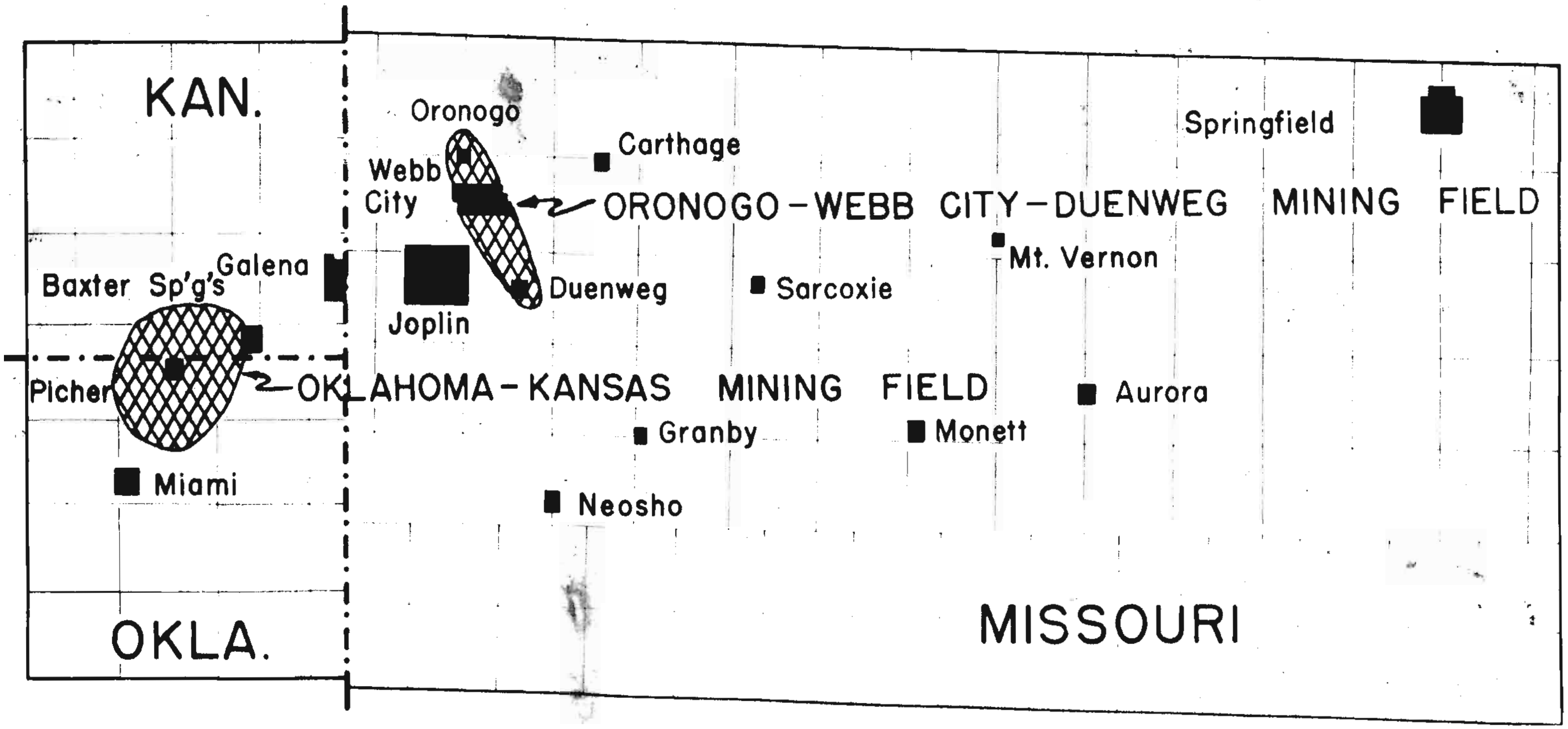
The field work was accomplished during the months of July, and August 1945; the data obtained therefrom and the analysis presented in this dissertation apply to the practice in effect at that time.

Table of Contents

List of Illustrations

List of Tables

TRI-STATE MINING DISTRICT



SCALE IN MILES 0 5 10

Introduction

The Tri-State mining district includes an elliptical area in southwestern Missouri, southeastern Kansas, and northeastern Oklahoma. Lengthwise it extends roughly from Springfield, Missouri, to Miami, Oklahoma, a distance of about 100 miles. The tract ranges from a few miles to 30 miles in width. (See Figure 1).

This zinc-lead district has continued for 60 years to lead all other fields supplying such metals both in production and economy. To meet war demands for zinc and lead, the Eagle-Picher Mining Company reopened many marginal mines, which prior to World War II had become inactive, and initiated a program of mine mechanization so that these marginal mines could be economically worked.

Clarke[1] has described several of the new mining methods that have been developed. One of the latest stages of mine mechanization has been the use of jumbos to facilitate drilling.

Briefly, the jumbo consists of two or three drills mounted on an adjustable boom. The boom is affixed to a caterpillar tractor. The drills may operate on either long carriage-sashes or short carriage-sashes. For convenience, jumbos equipped with long sash drills or those equipped with short sash drills are hereinafter referred to as long sashes or short sashes respectively, as the case may be.

Forrester and Taylor[2] have described the construction and operation

1. Clarke, S. S., Mining methods, Eagle-Picher number, Engineering & Mining Journal, Vol. 144, No. 11, pp. 80-89, (Nov., 1943).

2. Forrester, J. D., and Taylor, J. F. A., A comparative analysis of some recent mining practices in the Tri-State mining district. Missouri School of Mines & Metallurgy. Tech. series, Vol. 16, No. 1, 1945. pp 64.

of jumbo machines. Their work was undertaken as a comparative analysis of the old (post and/or tripod) and the new (jumbo machine) methods of drilling to determine the reasons for the improvement in mining efficiency attributed to the latter.

Initially the short sash jumbo crews consisted of two men per drill and thus such a jumbo fitted with two drills required a crew of four men. Forrester and Taylor[3] have stated that "The short sash jumbo, as compared with the long sash, suffers from the disadvantages of a lesser rate of drilling and the present requirements of four men in the jumbo operating crew. The relatively small period during which the helpers are engaged in "changing" and the large amount of time spent waiting for the event, together with other extraneous helper activities, raises the question that the short sash machines and post mounted drills with respect to manpower requirements, might possibly be worked more efficiently without helpers. Though it is possible to make, from the data gathered, an approximate estimate of the effects of this suggested modification it is felt that such an estimate would be based on untenable assumptions and that it would be qualitative rather than quantitative. Accordingly, the matter is left open at present but it is hoped that at some future date a time-study and comparative analysis may be made of the operations of drilling machines in such a cycle".

The purpose of this present study is to make such a quantitative analysis, as is above deemed desirable, of various distributions of man-power in the drilling crews. That is, to comparatively analyse the effects which accrue in drilling

3. Forrester, J. D. and Taylor, J. F. A., Op. cit. p. 62

procedures by using crews of different sizes in operating all types of jumbos and post mounted drills.

Geology

The geology of the Tri-State district has been adequately described by Fowler and Lyden[4], ~~and~~ by Weidman[5], and others. Briefly the principal ore-bearing formation is the Boone of lower Mississippian Age. The ore minerals are sphalerite and galena with which are associated marcasite, pyrite, and chalcopyrite and more rarely other accessory sulphide minerals.

The ore bodies occur in a zone 50 to 150 feet thick in the upper half of the Boone formation. In the mining of the ore bodies, there are two terms that have been adopted to indicate the manner under which the mining operations are carried on; namely, sheet ground excavations which extend laterally over a wide area, and high ground workings which have greater vertical extent in comparison to their lateral limits. The beds designated as O, P, and Q are the most important ore-bearing strata in the sheet ground mines.

Fowler[6] has described the O, P, and Q beds of the Boone formation as: "O, 8-9 ft. thick. Some limestone and abundant chert; gray, dense, in bands and round, flat nodules; an important sheet ground ore zone"... "P, 8-11 ft. thick. Chert, gray, dense; and limestone, gray, massive; mineralized locally"....."Q, 17-18 ft. thick. Chert, gray, dense; and limestone, gray, massive; mineralized locally".

---

4. Fowler, G.M., and Lyden, J.P., The ore deposits of the Tri-State district. Amer. Inst. Min. & Met. Engrs. Trans. Vol. 102, pp. 206-251, (1932).

5. Weidman, S., the Miami-Picher zinc-lead district, Oklahoma. Economic Geol. Vol. 28, Connecticut, 1933, pp. 82-84.

6. Fowler, G.M., Structural control of ore deposits in the Tri-State zinc and lead district. Engr. & Min. Jour., Vol. 139, No. 9, pp. 46-51 (September, 1938).

The physical characteristics of the rock in any mine vary considerably from porous cavernous material to hard massive chertified material.

Drilling Procedure and Mining Practice

The general mining practice of the Tri-State district is that outlined by Clarke[7]; namely, the room and pillar system. The pillars are irregularly spaced and range from 20 to 60 feet apart and are of such dimension that from 8 to 15 per cent of the area included within the overall limit of any mine tract is not removed.

In sheet ground mining, in which the time studies of this analysis were made, the stopes range from 8 to 16 feet in height. The entire height is drilled by the use of jumbos. Prior to the advent of jumbo drilling, stopes that were higher than 10 feet were mined by a bench and heading method. This practice necessitated the use of both post-mounted drills and tripod-mounted drills. Similarly, in high ground mining the practice was to drill for advance by the heading and bench system. The present procedure is to drill progressively upwards from the floor, the jumbo climbing the broken ore after each blast.

General practice in drilling sheet ground is to use a six hole round, namely two stope holes, two breast holes, and two roof holes (see Plate 1). The holes are spaced 4 to 6 feet apart. In the event of an irregularity in the rock face being drilled, the drill round ordinarily is modified and the holes are arranged so that the next face, which develops after blasting, may be drilled with the standard round of six holes. Standardization of the drilling round is beneficial to

7. Clarke, S. S., *Op. cit.*, pp. 80-89.

jumbos because to obtain maximum efficiency the two drills must operate simultaneously. Occasions arise in which only one hole is to be drilled and in such cases the other drill is idle and nonproductive.

In January, 1946, a three-drill, long sash jumbo was being operated successfully. The drilling round consisted of 9 holes to the face; namely, three stope holes, three breast holes, and three roof holes (see Plate 2). The three drills are mounted on a Model 60 Caterpillar tractor frame whereas the two drill system is mounted on a Model 30 Caterpillar frame. The former tractor is much more stable than the latter and thus less vibration and/or movement of the boom takes place during the drilling of holes[8]. Air is delivered to the drills at about 80 pounds pressure.

Blasting

Blasting is accomplished by using 1¼ x 8 inch semi-gelatin cartridges that split under the impact of the tamping stick. Primer cartridges are inserted into cardboard tubes to prevent the caps from coming in contact with the sides of the hole, in the event that the cap had not been correctly placed in the cartridge. All stope holes are double primed to insure firing. Holes are loaded by the powderman in the afternoon and blasted after the end of the shift. The order of firing is shown in Plates 1 and 2.

Transportation

Haulage of ore is accomplished in four ways; namely, by mules, tail-ropes, battery locomotives, and rubber-tired, battery-trucks. Each type

8. Clarke, S. S., Oral communication.

of haulage system has a definite field of application, that is, the use of mules is only practicable on haulage ways that are nearly level; tail-rope haulage is applicable to variable grades and sharp curves; battery locomotives are most efficiently operated on mainline tracks; and truck haulage, the most recent form of mechanization[9], is applicable to mines where grades of 12 per cent or more do not occur too frequently. Truck haulage is especially useful in mines that have been reopened, and where both time and economy are highly essential. That is, it requires less capital expenditure and less manpower to equip a mine with a truck haulage system than to install the tracks, cans, locomotives, cars, or tail-rope equipment which are necessary to operate the other haulage types.

Loading

There are two types of loading systems; namely, slusher loading and power-shovel loading. Slusher loading is accomplished by using caterpillar-mounted ramps equipped with 3-drum slusher hoists. The caterpillar ramps are powered by either air or electric motors. The slushers load directly into either cans of 0.6 ton capacity, or into 1¼ ton end-dump mine cars, or into trucks of 3½ ton capacity, as the case may be. Power-shovel loading was introduced in the latter months of 1941 because of the pending man-power shortage. The power-shovels, operated with air motors, dump directly into cans. As with the methods of haulage, both types of loading have their respective places in mining operations.

9. Clarke, S. S., Rubber-tired blitz buggies haul ore underground. Engineering & Mining Journal, Vol. 145, No. 12, pp. 88-90, (December 1944).

Slusher hoists are advantageous wherever there is room to operate them whereas power-shovels are applicable to narrow, low headings.

Hoisting

Can-hoisting and skip-hoisting are the two chief methods of hoisting used in the Tri-State district. The cans, which are hoisted by electric power, are moved at speeds between 1500 and 1800 feet per minute*. The can-system has a definite advantage over the skip system in that the capital outlay is approximately one-fourth that of the skip system. Skips, with capacities ranging from 2 to 3½ tons, are used in mines from which tonnages in excess of 400, the practical limit of the can system, are desired per shift. Hoisting cables range in size from 5/8" for the can systems to 1 1/2" for the skip systems.

Safety

Safety regulations which apply to drilling are, on the whole, adhered to. At the beginning of the shift the entire working area is sprayed with water. Loose slabs at the face and in the roof are removed by the roof trimmers. All holes are drilled wet, and goggles are provided the men to be used while collaring a hole.

Time Study Application & Procedure

Truscott[10] has concisely defined a time study as being "......comprehensive observations on routine work, in which the timing of definite occupations during that work plays an essential and preponderating part."

---

* Men are not hoisted at a speed greater than 500 feet per minute.

10. Truscott, S.J., Scientific management in mining, Engineering & Mining Journal, 128, pp. 133-137, July 27, 1929.

Harley[11] is of the opinion that time study procedures are most applicable to machine shop work where operations on each machine are standardized. Each cycle of operation uses the same tools, the same motions, and consumes that same amount of time.

In mining, although the basic cycle is the same daily, there are however, many unavoidable occurrences that are unpredictable and non-standardized. These non-cyclic variations must be taken into consideration if a time-study procedure is to be applied to drilling. For example, the drilling speed of a drill is a function of the drill itself and the character and hardness of the ground. The time consumed in occupations such as changing steel and setting up depend, however, more directly upon the men themselves, and thus, the type of men used in making the tests has a direct bearing on the efficiency of the operation.

Both the time-study method and the classification procedure used in this work are similar to ~~that~~ those used by Forrester and Taylor[12]. That is, the time at which each man in the drilling crew completes an occupation is recorded on an Observation Sheet alongside a note of that activity. The field observations are posted to a Summary Sheet. Upon the completion of a study of a particular drilling method, the daily activities of each man are entered on a Consolidation Sheet (see Tables 1-7). The similarity of the procedure used in this work with that

11. Harley, G. T., Time-study methods for mining operations, Engineering and Mining Journal, Vol. 123, pp. 722-729, 1927.

12. Forrester, J. D., and Taylor, J. F. A., op.cit., p. 21

followed by Forrester and Taylor is intentional so that a comparison of the results obtained from the data of the present study can be conveniently ~~may be most~~ readily made with the former practices described in their paper.

Before beginning an analysis of the effect of different size crews as applied to drilling the cyclic occupations of the drillers will be defined.

The operation of drilling during a work-shift is broken down into eleven subdivisions and each subdivision is further detailed ~~broken down~~ into one or more elements. Definitions of the elements are as follow:

1. Travel Time---the time utilized by the men journeying between the shaft collar and the underground working place when going on and off shift. As it is the practice in the Tri-State District for the men to lunch on the surface, four trips daily are included.

2. Face Preparation---time spent in performing the essential preliminary acts before the jumbo machine or post and/or tripod is moved to drill a round.

"Muck Out" --time consumed by a portion of the crew in removing muck or rock from the face so that drilling may proceed.

"Wait on Muck Out" --one man usually can satisfactorily muck out and unless the other members of the drilling crew are engaged in another occupation they are charged to wait on muck out.

"Face Inspection" --to obtain the best results from drilling, the face is inspected to decide the most advantageous position for the jumbo to be placed or the post to be erected, as the case may be.

"Barring Down" --time spent by any portion of the drilling crew in removing loose slabs and/or boulders from the roof or face so that drilling may proceed safely.

"Wait on Bar Down" —prior to drilling, the jumbo may be utilized by roof trimmers. ~~This~~ The delay in which the drilling crew is idle is charged to this category.

"Hose Down" —water is sprayed on the working place to allay dust.

"Wait on Hose Down" —as it is necessary for only one man to hose down, the remainder of the crew is idle.

"Moving Boulders" —large boulders and/or slabs sometimes prohibit the jumbo machine from reaching the working place. Time spent in removing the obstruent material so that the jumbo may proceed to the face is charged to moving boulders.

3. Drill Preparation—the time consumed in the placing of the jumbo machine or post (or tripod) in such a position that it may do productive work, that is, the drilling of holes.

"Moving Jumbo" —the time spent in moving the jumbo machine from one face to the next. The time consumed in moving the jumbo to and from the working face at the beginning and at the end of the shift respectively is also charged to this category. On both the long sash and short sash jumbos one man drives the machine and the remainder of the crew is available for dragging the hoses. In cases where the crew is made up of two men, the hoses are usually disconnected.

"Erecting Post" —in post erection the counterpart of "Moving Jumbo" is the dismantling of the equipment after drilling and erecting it at the next face to be drilled.

"Setting Up" —with jumbo drilling one movement of the boom, which supports two drills, permits the drilling of two holes simultaneously but with post drilling each type of hole requires a different position of the arm. Setting up also includes time allotted to alignment and clamping of the drilling machine and the placing of the steel in the chuck. With three men operating two post-mounted drills, occasions arise in which three men may perform one task.

4. Drilling, Productive Elements----the time utilized by drilling operations which are essential to the actual drilling of each and every hole.

"Drilling" ----time consumed by the drillers in operating their machines including the time spent in successfully collaring a hole, provided that time is less than one minute.

"Changing Steel" ---as it is necessary, especially for the short sash and post-mounted drills, frequently to change steel, the time involved in this occupation by both driller and the helper is charged to "Changing Steel". The usual practice in changing steel is for both the driller and his helper to aid one another in unscrewing the bit from the short steel and putting it on the longer one. The helper then places the longer steel in the drill chuck.

"Changing Bit" ---this category is peculiar to the long sash machine at the Leapod mine in which exceptionally hard material is encountered. Frequent replacements of the dulled bits are necessary to maintain the desired number of drill holes per shift. In changing a bit the dulled bit must be hammered loose and a sharpened one selected that is either the same size or smaller in diameter to permit the steel to re-enter the hole and the drilling to proceed. This occupation is seldom in excess of three minutes.

"Help Other Drilling" —on both the long sash and short sash machines, where either there is no helper or the helper is occupied in another task, it has been found advantageous for both drillers to aid each other during drilling and/or changing steel.

The above classifications under "Drilling, Productive Elements" are not individually similar to those used by Forrester and Taylor[13] because the distribution of manpower in the drilling crews necessitates elements in which individual occupations may be included, however, the ~~summtions~~ essentials of the elements of both studies are equivalent.

5. Drilling, Non-Productive Elements——this is the time consumed in those occupations which are ~~essential~~ necessary to the drilling procedure but, which within themselves, do not result in a deepening of the drill hole.

"Wait for Changing" —this time expenditure by the helper occurs during most of the time that drilling is in progress. The helper stands by waiting for the next change of steel. If one driller has completed his hole before the other driller, or is drilling an extra hole, the helper, who is in reality not only waiting on the other drill or waiting on extra hole but also waiting for changing, is charged to "Wait for Changing."

"Clean Out Hole" —upon the removal of a stuck steel the hole is usually raked clean with a stick designed especially for this purpose. "Clean out Hole" resulting from stuck steel is frequently encountered in vuggy ground.

"Blow Holes" —at the completion of a round, and whenever necessary during the drilling of a round, the holes are cleaned by blowing them clean with air through a specially designed pipe. Some jumbo

13. Forrester, J. D., and Taylor, J. F. A., op.cit., p. 25

machines have an extra air-cock to which is attached the hose and blowing-pipe. Time spent in making a connection on machines not equipped with additional air-cocks is charged to "blow holes."

"Wait on Blow Holes" —as the efforts of only one or two men are required to satisfactorily blow the holes, the remainder of the crew wait for the next move of the machines. If it is necessary for a hole to be blown during drilling operations the other driller and the helper stand aside to avoid flying pieces of rock ~~blown out~~ ejected by the air.

"Collar Hole" —it may be difficult to start, or collar, a drill hole and if such is the case, a new set-up of the equipment may be required. Time in excess of one minute spent in starting a hole is entered under "Collar Hole."

6. Productive Delays——this is the time in which only half of the drilling capacity is being utilized on productive work because, in jumbo drilling, occasions arise when one drill will be idle while the other is working. This category is not applicable to post drilling.

"Wait on Other Drill" —in jumbo drilling, delays occur when one drilling machine completes a drill hole before the other machine has finished its hole.

"Wait on Extra Holes" —it may be necessary to drill holes in addition to those of the standard round. Time spent in such a procedure is a productive delay and is charged to "Wait on Extra Holes."

7. Non-Productive Delays——during the drilling cycle, time may be taken up by delays that are neither productive nor essential.

"Stuck Steel" --if a drill steel becomes stuck or immovable in the drill hole the progress of the drilling is interrupted. The delay caused by this interruption is entered as "stuck steel."

"Wait on Stuck Steel" --a delay caused by stuck steel on one drilling machine ~~during the drilling cycle~~ which prohibits the other machine from doing productive drilling. The delayage of the latter is charged to "wait on stuck steel."

8. Supply Delays----these delays occur whenever it is necessary for any member of a crew to be absent from the drilling operation because of a lack of supplies such as bits, steel, oil, etc.

"Collect Supplies" --if supplies are needed during the shift they are obtained from either the underground or surface storage rooms.

"Wait on Collect Supplies" --time spent by the drillers while waiting for supplies.

9. Maintenance Delays----an expenditure of time necessary to maintain the equipment in working order.

"Hose Repairs" --when an air or water hose breaks, the drilling cycle is interrupted until the repairs are accomplished.

"Drill Maintenance and Repairs" --time spent in repairing the drills or sashes during the drill shift.

"Wait on Drill Maintenance and Repairs" --as it may only require the service of one or two men to make the drill or sash repairs the remainder of the crew may be idle.

"Repairs to Jumbo" --a delay in the drilling procedure necessitated by repairs to the jumbo machine during the shift.

"Oiling" --the oiling as routine maintenance, of both the drills and the sashes. ~~is a routine maintenance job~~.

10. Miscellaneous Delays---the time consumed by infrequent and non-predictable delays.

"Recovering Steel" --if a steel breaks in a hole that is nearly completed, the driller, or helper, attempts to retrieve the broken portion with the aid of the raking stick and thus recover the hole.

"Straighten Steel" --the drill steel may become bent when either a drilling machine has moved out of alignment or during the freeing of a stuck steel.

"Wait for Power Cable to be Moved Forward" --occasions arise when the drilling face has progressed forward to such an extent that the jumbo is unable to reach the working place without extending the power cable.

"Wait on Water" --the working place may become inundated. Time spent in overcoming this condition is charged to wait on water.

"Move Main Pipe Lines" --time consumed in advancing the main air and water lines.

11. Idle Time---time during which drilling operations are not being furthered.

"Excessive Rest" --if the drilling crew is idle without apparent reason the time consumed is charged to this category.

"Wait at End of Shift" --the time which passes between the completion of the day's drilling and when the men are hoisted at the end of the shift.

Comparison and Interpretation of the Effects of Varying Crews in Drilling

Tables 1, 2, 3, 4, 5, 6, and 7 are consolidation sheets on which the data of each day's study are summarized. The symbols D and H denote the driller's time and the helper's time on a machine, and L or R denotes the left drill or right drill, as the case may be.

Plates 3, 4, 5, 6, 7, 8, and 9 have been compiled from the above tables to give a comparative graphical picture of the time distribution of both the occupations and their elements. The resulting sectors represent the percentages shown in the consolidation sheets.

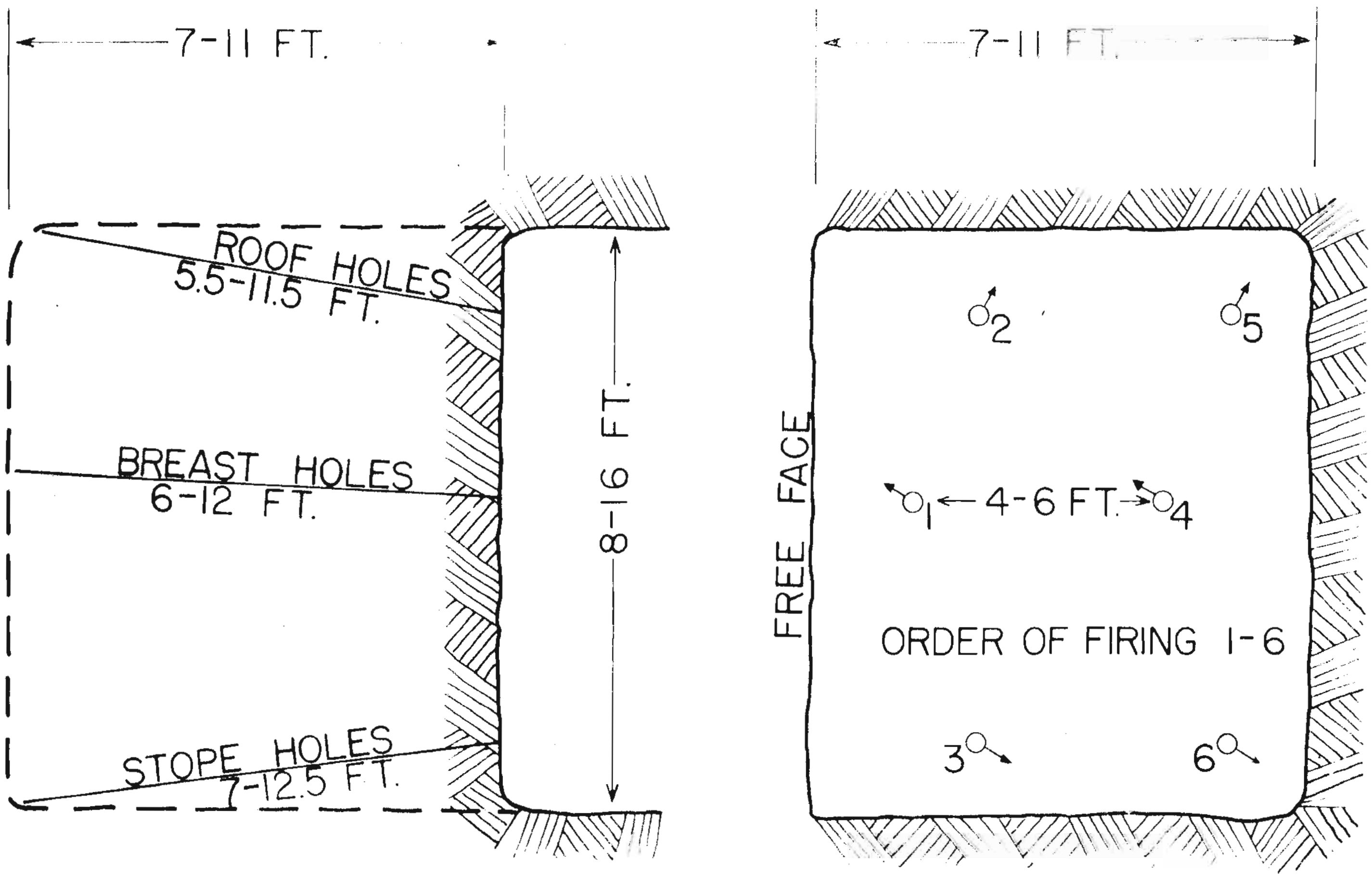
Tables 1, 2, and 3 represent the operational data for drilling crews of 2, 3, and 4 men respectively on the short sash jumbo; tables 4 and 5 represent the data for 2 and 3 men respectively on the long sash jumbo; and tables 6 and 7 show the data for 2 and 3 men on post-mounted drills.

Plate 10 is a graph of Drill Preparation, Drilling, Productive Elements, and Drilling, Non-Productive Elements and the total per cent of time consumed per shift. This graph was made so that a graphical picture of the three most time-consuming operations may be readily compared.

Plate 11 depicts the amount of drilling (in feet) accomplished by all types of drilling.

The elements of Drill Preparation and Productive Drilling are cyclic and standardized and thus a further breakdown of the occupations of the above elements is given.

In order that the variable jumbo crews may be compared they are reduced to a common shift basis, that is, two, three, and four man crews are based on one 8 hour shift of 480, 960, and 1920 man-minutes respectively.

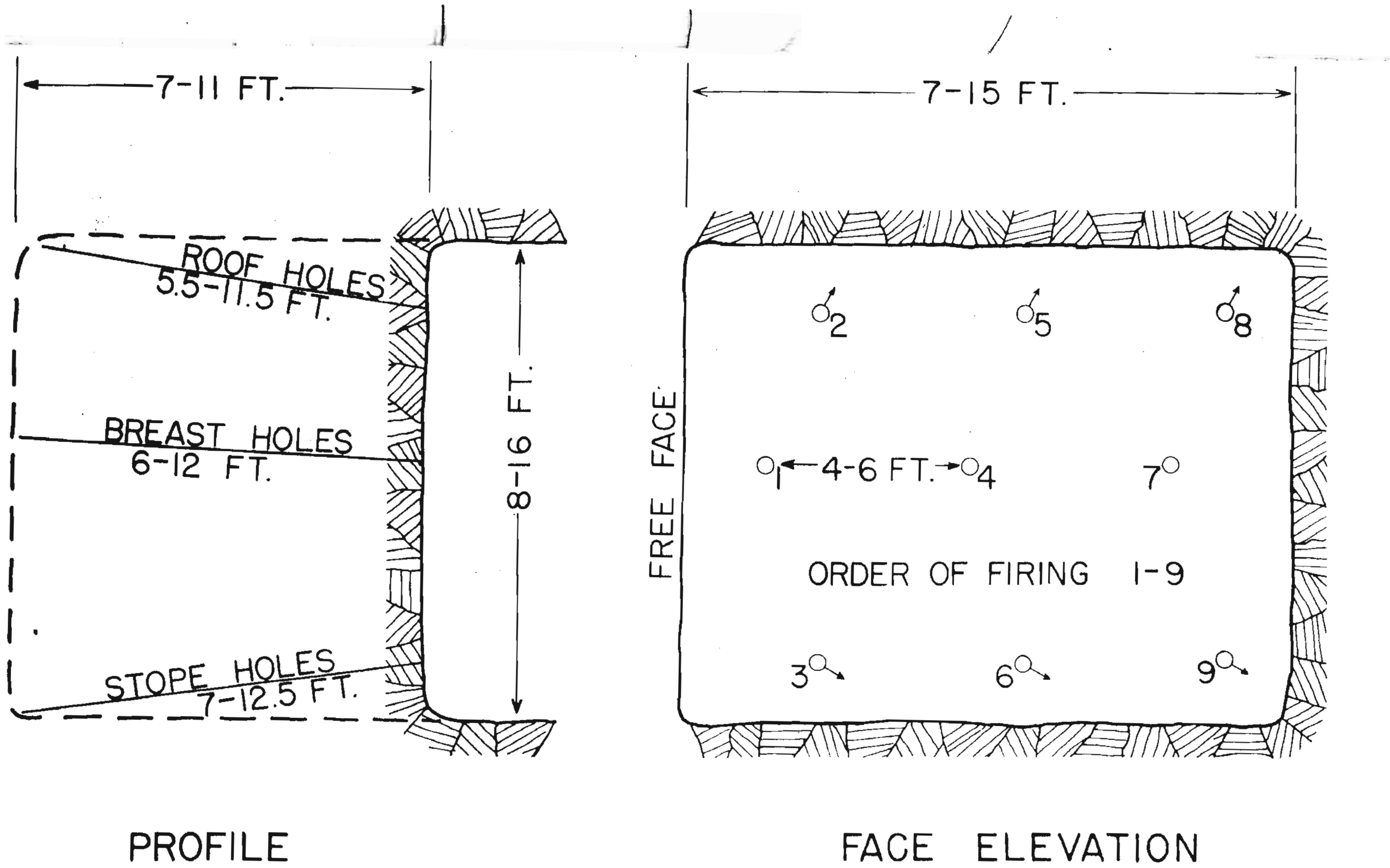


PROFILE

FACE ELEVATION

STANDARD SIX HOLE ROUND

Plate I



STANDARD NINE HOLE ROUND

Plate II

Table I - Drilling
Time Study Consolidation Sheet
Short Sash Jumbo — 2 Man Crew
All time given in minutes

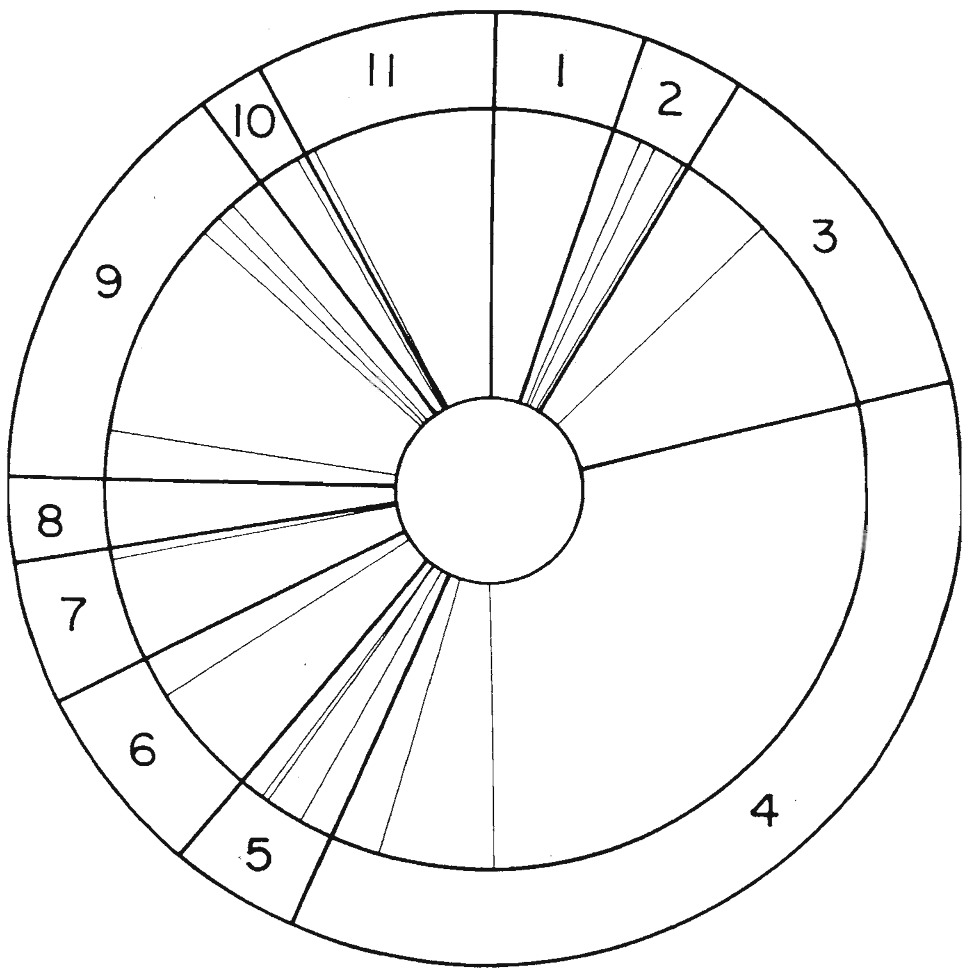
		Day	1	2	3	4	Total	Average per Shift	Percent	
1-TRAVEL TIME		L D	22	24	24	30				
		R D	22	23	24	30	199	49.75	5.18	5.18
2-FACE PREPARATION	Muck Out	L D	10	0	5	4				
		R D	4	8	5	13	49	12.25	1.28	
	Wait on Muck Out	L D	4	4	0	8				
		R D	6	0	0	4	26	6.50	.68	
	Face Inspection	L D	6	5	7	5				
		R D	11	5	7	6	52	13.0	1.35	
	Barring down	L D	0	0	0	0				
		R D	0	0	0	0	0	0	0	
	Wait on Barring down	L D	0	0	0	0				
		R D	0	0	0	0	0	0	0	
	Hose down	L D	0	0	0	0				
		R D	0	0	0	0	0	0	0	
	Wait on Hose down	L D	0	0	0	0				
		R D	0	0	0	0	0	0	0	
	Moving Boulders	L D	1	0	0	0				
		R D	6	0	0	0	7	1.75	.18	3.49
3-DRILL PREPARATION	Moving Jumbo	L D	35	11	14	23				
		R D	30	10	14	21	158	39.50	4.11	
	Setting Up	L D	40	27	52	50				
		R D	39	29	45	44	326	81.5	8.49	12.60
	Drilling	L D	172	109	160	168				
		R D	111	100	136	146	1122	280.5	29.22	
4-DRILLING PRODUCTIVE ELEMENTS	Changing Steel	L D	26	19	22	30				
		R D	19	24	21	28	189	47.25	4.92	
	Help Other Drilling	L D	15	2	2	10				
		R D	12	5	0	11	57	14.25	1.48	35.62

Table I continued

		Day	1	2	3	4	Total	Average per shift	Percent	
5—DRILLING NON PRODUCTIVE ELEMENTS	Clean Out Hole	L D	14	26	0	0				
		R D	8	1	0	3	52	13.	1.35	
	Blow Holes	L D	7	7	6	6				
		R D	11	11	6	6	60	15.	1.56	
	Wait on Blow Holes	L D	3	0	6	0				
		R D	0	0	0	0	9	2.25	.23	
	Collar Hole	L D	2	1	4	7				
		R D	9	9	5	10	47	11.75	1.23	4.37
6—PRODUCTIVE DELAYS	Wait on Other Drill	L D	0	21	19	5				
		R D	47	46	16	30	184	46.	4.79	
	Wait on Extra Hole	L D	4	0	23	0				
		R D	15	0	0	0	42	10.5	1.09	5.88
7—NON-PRODUCTIVE DELAYS	Stuck Steel	L D	6	50	0	37				
		R D	23	9	29	20	174	43.5	4.54	
	Wait on Stuck Steel	L D	0	0	0	3				
		R D	0	0	0	11	14	3.5	.36	4.90
8—SUPPLY DELAYS	Collect Supplies	L D	10	33	19	3				
		R D	4	26	7	10	112	28.	2.92	
	Wait on Collect Supplies	L D	0	0	0	0				
		R D	0	0	0	0	0	0	0	2.92
9—MAINTENANCE DELAYS	Hose Repairs	L D	14	1	0	11				
		R D	28	2	23	0	79	19.75	2.06	
	Drill Main. & Repairs	I D	0	113	32	27				
		R D	0	98	37	53	360	90	9.39	
	Wait on Drill Main. & Repairs	L D	0	0	0	0				
		R D	0	42	0	0	42	10.5	1.09	

Table I continued

		Day	1	2	3	4	Total	Average per Shift	Percent	
9-MAINTENANCE DELAYS CONT'T.	Repairs to Jumbo	L D	0	0	6	0				
		R D	0	0	26	0	32	8	.83	
	Oiling	L D	11	4	4	3				
		R D	3	8	7	4	44	11	1.15	14.52
10-MISCELLANEOUS DELAYS	Wait for Power Cable to be Moved Forward	L D	0	0	35	0				
		R D	0	0	35	0	70	17.5	1.82	
	Wait on Scraper Hoist to be Moved	L D	0	0	9	0				
		R D	0	0	9	0	18	4.5	.47	2.29
11-IDLE TIME	Excessive Rest	L D	7	0	3	0				
		R D	2	0	0	0	12	3.	.31	
	Wait at End of Shift	L D	70	24	28	30				
		R D	70	24	28	30	304	76	7.92	8.23



TIME DISTRIBUTION CHART
SHORT SASH JUMBO
2-MAN CREW

Plate III

Table II Drilling

Time Study Consolidation Sheet

Short Sash Jumbo -- 3 Man Crew

All time given in minutes

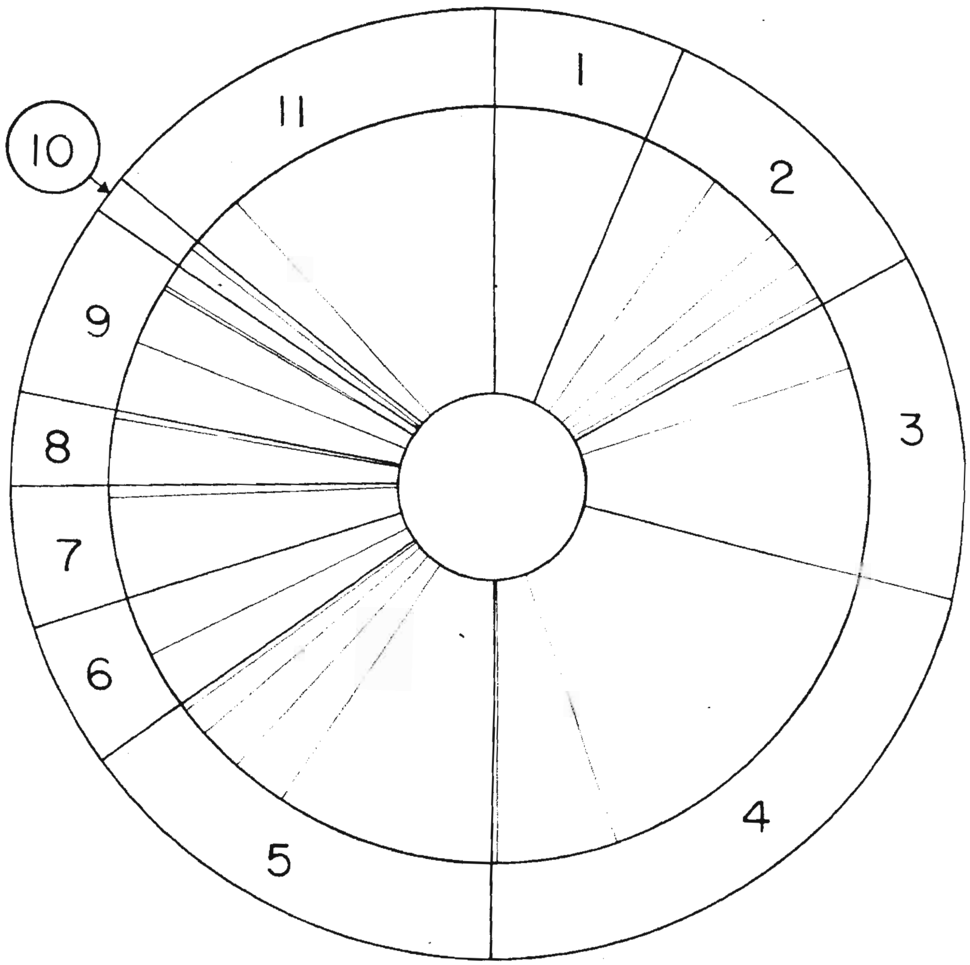
		Day	1	2	3	Total	Average per Shift	Percent	
1-TRAVEL TIME		L D	33	30	31				
		H	33	33	31				
		R D	33	33	31	288	96	6.67	6.67
2-FACE PREPARATION	Muck Cut	L D	13	8	7				
		H	35	24	20				
		R D	29	5	15	156	52	3.61	
	Wait on Muck Cut	L D	35	23	8				
		H	13	13	7				
		R D	19	26	0	144	48	3.33	
	Face Inspection	L D	15	4	7				
		H	11	4	0				
		R D	11	4	7	63	21	1.46	
	Barring down	L D	0	0	0				
		H	0	0	0				
		R D	0	0	0	0	0	0	
	Wait on Barring down	L D	0	0	27				
		H	0	0	27				
		R D	0	0	27	81	27	1.88	
	Hose down	L D	0	0	0				
		H	0	0	0				
		R D	0	0	0	0	0	0	
	Wait on Hose down	L D	0	0	0				
		H	0	0	0				
		R D	0	0	0	0	0	0	
	Moving Boulders	L D	3	0	0				
		H	3	0	0				
		R D	3	0	0	9	3	.21	10.49
3-DRILL PREPARATION	Moving Jumbo	L D	18	10	17				
		H	11	10	13				
		R D	18	10	17	124	41.33	2.87	
	Setting Up	L D	35	57	52				
		H	31	57	39				
		R D	34	55	47	398	132.7	9.22	12.09

Table II continued

		Day	1	2	3	Total	Average per Shift	Percent	
4-DRILLING, PRODUCTIVE ELEMENTS	Drilling	L D	102	146	117				
		H	0	0	0				
		R D	130	88	108	691	230.33	15.99	
	Changing Steel	L D	20	28	22				
		H	29	32	30				
		R D	26	16	23	226	75.33	5.23	
	Help Other Drilling	L D	2	0	0				
		H	0	0	0				
		R D	0	1	1	4	1.33	.09	21.31
5-DRILLING, NON-PRODUCTIVE ELEMENTS	Wait for Changing	L D	0	0	0				
		H	137	146	114				
		R D	0	0	0	397	132.33	9.19	
	Clean Out Holes	L D	11	19	0				
		H	5	17	0				
		R D	27	8	9	96	32	2.23	
	Blow Holes	L D	2	15	0				
		H	9	10	0				
		R D	23	14	5	79	26.33	1.83	
	Wait on Blow Holes	L D	11	14	5				
		H	0	19	0				
		R D	0	11	0	60	20	1.39	
	Collar Hole	L D	2	0	3				
		H	1	1	4				
		R D	2	4	3	20	6.66	.46	15.10
6-PRODUCTIVE DELAYS	Wait on Other Drill	L D	41	3	13				
		H	0	0	0				
		R D	3	26	16	102	34	2.36	
	Wait on Extra Holes	L D	36	0	0				
		H	0	0	0				
		R D	0	57	18	111	37	2.57	4.93
7-NON-PRODUCTIVE DELAYS	Stuck Steel	L D	7	21	19				
		H	30	26	11				
		R D	43	16	8	181	60.33	4.19	
	Wait on Stuck Steel	L D	11	3	5				
		H	0	0	0				
		R D	0	4	3	26	8.66	.60	4.79

Table II continued

		Day	1	2	3	Total	Average per Shift	Percent	
8—SUPPLY DELAYS	Collect Supplies	L D	4	5	0				
		H	50	2	53				
		R D	4	8	10	136	45.33	3.15	
	Wait on Collect Supplies	L D	0	0	5				
		H	0	0	0				
		R D	0	0	0	5	1.66	.12	3.27
9—MAINTENANCE DELAYS	Hose Repairs	L D	1	0	0				
		H	0	0	0				
		R D	0	0	0	1	.33	.02	
	Drill Maint. & Repairs	L D	15	11	55				
		H	0	8	16				
		R D	3	12	14	134	44.66	3.10	
	Wait on Drill Main. & Repairs	L D	0	0	3				
		H	10	0	38				
		R D	12	0	39	102	34	2.36	
	Repairs to Jumbo	L D	0	0	0				
		H	6	0	0				
		R D	0	0	0	6	2	.14	
	Oiling	L D	8	9	2				
		H	7	4	2				
		R D	6	3	7	48	16	1.11	6.73
10—MISCELLANEOUS DELAYS	Wait on Powderman Using Jumbo	L D	8	0	0				
		H	8	0	0				
		R D	8	0	0	24	8	.55	
	Straighten Steel	L D	0	0	0				
		H	0	0	2				
		R D	0	0	0	2	.66	.05	
	Move Main Pipe lines	L D	0	0	10				
		H	0	0	10				
		R D	0	0	0	20	6.66	.46	1.06
11—IDLE TIME	Excessive Rest	L D	2	8	21				
		H	0	8	21				
		R D	0	13	21	94	31.33	2.17	
	Wait at End of Shift	L D	47	66	51				
		H	47	66	51				
		R D	47	66	51	492	164	11.38	13.55



TIME DISTRIBUTION CHART
SHORT SASH JUMBO
3-MAN CREW

Plate IV

Table III Drilling*
<u>Time Study Consolidation Sheet</u>
<u>Short Sash Jumbo — 4 Man Crew</u>
All times given in minutes

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
1-TRAVEL TIME		D	37	36	40	39	48				
		L H	40	39	40	35	43				
		D	40	36	43	38	45				
		R H	37	39	43	32	43				
		Total	154	150	166	144	179	793	158.6	8.25	<u>8.25</u>
2-FACE PREPARATION	Wait on Muck Out	D	0	0	0	0	0				
		L H	0	0	0	0	0				
		D	0	0	0	0	0				
		R H	0	0	0	0	0				
		Total	0	0	0	0	0	0	0	0	
	Face Inspection	D	5	15	20	1	12				
		L H	2	15	6	9	6				
		D	2	15	17	13	12				
		R H	5	15	6	1	3				
		Total	14	60	49	24	33	180	36.0	1.88	
	Barring down	D	7	0	0	15	17				
		L H	0	22	0	0	0				
		D	0	0	0	0	0				
		R H	0	22	11	15	13				
		Total	7	44	11	30	30	122	24.4	1.27	
	Wait on Barring down	D	0	13	0	0	0				
		L H	7	0	0	0	8				
		D	7	22	0	0	17				
		R H	7	0	0	0	17				
		Total	21	35	0	0	42	98	19.6	1.02	
	Hose down	D	0	5	0	0	0				
		L H	0	0	18	0	9				
		D	0	2	0	0	3				
		R H	0	2	0	0	7				
		Total	0	9	18	0	19	46	9.2	0.48	
	Wait on Hose down	D	0	2	4	0	2				
		L H	0	2	0	0	2				
		D	0	2	0	0	2				
		R H	0	0	0	0	0				
		Total	0	6	4	0	6	16	3.2	0.17	

* Forrester, J. D. and Taylor, J. F. A., <u>op.cit.</u>, pp. 29-32 Table V

Table III continued

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
2-FACE PREPARATION CON'T.	Moving Boulders	LD	0	0	0	0	3				
		LH	0	0	0	0	3				
		RD	0	0	0	0	3				
		RH	0	0	0	0	3				
		Total	0	0	0	0	12	12	2.4	0.12	4.94
3-DRILL PREPARATION	Moving Jumbo	LD	21	31	14	19	27				
		LH	21	27	14	19	29				
		RD	21	26	14	19	27				
		RH	21	27	14	19	22				
		Total	84	111	56	76	105	432	86.4	4.50	
	Setting Up	LD	54	44	27	21	51				
		LH	47	39	27	21	51				
		RD	49	48	30	30	61				
		RH	49	40	30	30	58				
		Total	199	171	114	102	221	807	161.4	8.40	12.90
4-DRILLING, PRODUCTIVE ELEMENTS	Drilling & Changing	LD	175	141	126	81	181				
		RD	127	145	129	109	187				
		Total	302	286	255	190	368	1401	280.2	14.59	
	Changing	LH	37	33	32	21	37				
		RH	30	31	39	26	44				
		Total	67	64	71	47	81	330	66.0	3.44	18.03
5-DRILLING, NON-PRODUCTIVE ELEMENTS	Wait on Changing	LH	121	106	94	57	144				
		RH	94	113	87	83	142				
		Total	215	219	181	140	286	1041	208.2	10.84	
	Clean Out Hole	LD	0	2	0	0	0				
		LH	0	2	0	0	0				
		RD	0	0	0	0	0				
		RH	0	0	0	0	0				
		Total	0	4	0	0	0	4	0.8	0.04	
	Blow Holes	LD	11	8	2	0	0				
		LH	11	3	0	0	0				
		RD	0	18	12	9	13				
		RH	0	3	0	2	2				
		Total	22	32	14	11	15	94	18.8	0.98	

Table III continued

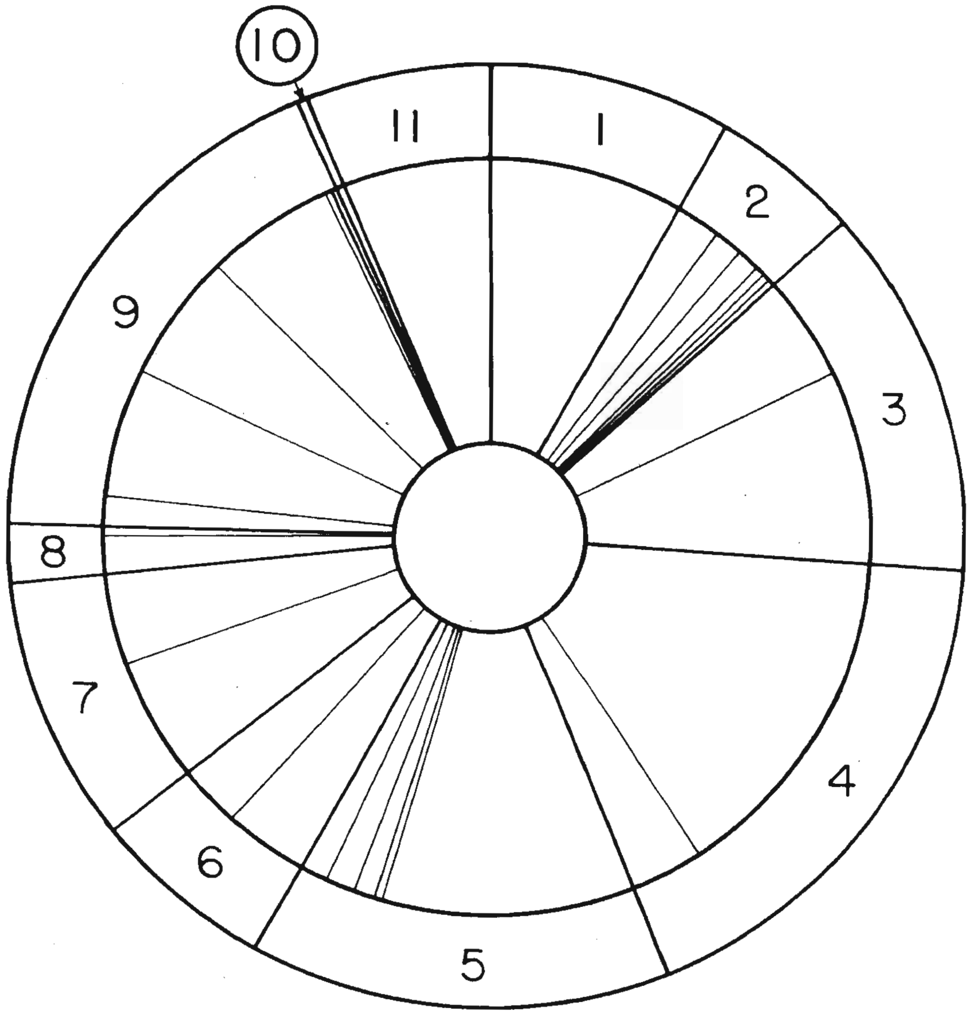
		Day	1	2	3	4	5	Total	Average per Shift	Percent	
5—DRILLING, NON-PRO. ELEMENTS CON'T.	Wait on Blow Holes	L D	0	11	8	6	8				
		L H	0	16	8	6	8				
		R D	7	6	0	0	0				
		R H	7	17	8	7	8				
		Total	14	50	24	19	24	131	26.2	1.37	
	Collar Hole	L D	8	0	0	0	7				
		L H	4	0	0	0	7				
		R D	4	21	0	6	4				
		R H	4	21	0	6	4				
		Total	20	42	0	12	22	96	19.2	1.00	14.23
6—PRODUCTIVE DELAY	Wait on Other Drill	L D	9	43	15	28	21				
		L H	9	41	17	26	21				
		R D	23	9	13	0	13				
		R H	23	8	13	0	13				
		Total	64	101	58	54	68	345	69.0	3.59	
	Wait on Extra Holes	L D	0	14	13	12	15				
		L H	0	14	13	12	15				
		R D	53	16	0	0	0				
		R H	53	16	0	0	0				
		Total	106	60	26	24	30	246	49.2	2.56	6.15
7—NON-PRODUCTIVE DELAYS	Stuck Steel	L D	78	27	9	6	9				
		L H	74	27	9	6	9				
		R D	3	19	17	56	31				
		R H	3	19	17	56	31				
		Total	158	92	52	124	80	506	101.2	5.27	
	Wait on Stuck Steel	L D	0	8	5	49	25				
		L H	0	8	5	49	23				
		R D	71	15	4	0	3				
		R H	68	9	7	0	5				
		Total	139	40	21	98	56	354	70.8	3.69	8.96
8—SUPPLY DELAYS	Collect Supplies	L D	5	0	0	0	0				
		L H	45	10	0	12	9				
		R D	0	0	0	0	3				
		R H	10	18	13	7	24				
		Total	60	28	13	19	36	156	31.2	1.63	
	Wait on Collect Supplies	L D	8	7	0	0	0				
		L H	0	0	0	0	0				
		R D	4	9	0	0	6				
		R H	0	0	0	0	0				
		Total	12	16	0	0	6	34	6.8	0.35	1.98

Table III continued

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
9—MAINTENANCE DELAYS	Hose Repairs	LD	21	0	0	4	0				
		LH	21	2	0	4	0				
		RD	23	0	0	4	0				
		RH	23	2	0	4	0				
		Total	88	4	0	16	0	108	21.6	1.13	
	Drill Mainte-ance & Repairs	LD	27	0	135	49	29				
		LH	0	0	139	48	29				
		RD	0	0	51	0	0				
		RH	0	0	34	0	0				
		Total	27	0	359	97	58	541	108.2	5.64	
	Wait on Drill Repairs	LD	0	0	38	0	0				
		LH	27	0	34	0	0				
		RD	27	0	125	42	20				
		RH	27	0	131	42	5				
		Total	81	0	328	84	25	518	103.6	5.40	
	Repairs to Jumbo	LD	0	0	0	125	0				
		LH	0	0	0	129	0				
		RD	0	0	0	129	0				
		RH	0	0	0	125	0				
		Total	0	0	0	508	0	508	101.6	5.29	
	Oiling	LD	0	0	0	0	2				
		LH	0	2	0	1	4				
		RD	5	2	1	0	7				
		RH	5	3	3	0	7				
		Total	10	7	4	1	20	42	8.4	0.44	18.72
10—MISCELLANEOUS DELAYS	Machine Off Sash	LD	2	0	0	0	0				
		LH	2	0	0	0	0				
		RD	2	0	0	0	0				
		RH	2	0	0	0	0				
		Total	8	0	0	0	0	8	1.6	0.08	
	Blasting Damage	LD	0	0	2	0	0				
		LH	0	0	2	0	0				
		RD	0	0	2	0	0				
		RH	0	0	2	0	0				
		Total	0	0	8	0	0	8	1.6	0.08	
	Straighten Steel	LD	0	0	0	0	0				
		LH	0	0	0	0	0				
		RD	0	0	0	0	0				
		RH	0	0	0	0	0				
		Total	0	0	0	0	0	0	0	0	

Table III continued

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
10—MISCELLANEOUS DELAYS (continued)	Direct Powder-Man	L D	0	0	0	0	0				
		L H	0	0	0	0	0				
		R D	0	0	0	0	0				
		R H	0	0	0	0	0				
		Total	0	0	0	0	0				
	Powderman Loading Holes	L D	0	0	0	0	0				
		L H	0	0	0	0	0				
		R D	0	0	0	0	0				
		R H	0	0	0	0	0				
		Total	0	0	0	0	0	0	0	0	
11—IDLE TIME	Excessive Rest	L D	0	25	1	0	0				
		L H	0	24	1	0	0				
		R D	0	21	1	0	0				
		R H	0	27	1	0	6				
		Total	0	97	4	0	6	107	21.4	1.11	
	Wait at End of Shift	L D	12	48	21	25	23				
		L H	12	48	21	25	23				
		R D	12	48	21	25	23				
		R H	12	48	21	25	23				
		Total	48	192	84	100	92	516	103.2	5.38	6.49



TIME DISTRIBUTION CHART
SHORT SASH JUMBO
4-MAN CREW

Plate V

Table IV Drilling*
<u>Time Study Consolidation Sheet</u>
<u>Long Sash Jumbo —— 2 Man Crew</u>
All times given in minutes

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
1-TRAVEL TIME		L	39	40	38	39	38				
		R	32	40	36	39	43				
		Total	71	80	74	78	81	384	76.8	8.00	<u>8.00</u>
2—FACE PREPARATION	Wait on Muck Out	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0	0	0	
	Face Inspection	L	16	24	22	18	12				
		R	22	24	8	18	16				
		Total	38	48	30	36	28	180	36.0	3.75	
	Barring down	L	12	14	0	0	0				
		R	0	0	0	0	0				
		Total	12	14	0	0	0	26	5.2	0.54	
	Wait on Barring down	L	0	0	0	0	0				
		R	4	12	0	0	0				
		Total	4	12	0	0	0	16	3.2	0.33	
	Hose Down	L	0	0	0	0	0				
		R	0	3	0	0	0				
		Total	0	3	0	0	0	3	0.6	0.06	
	Wait on Hose Down	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0	0	0	
	Moving Boulders	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0	0	0	
3—DRILL PREPARATION	Moving Jumbo	L	20	31	30.5	34	37				
		R	20	31	27.5	37	48				
		Total	40	62	58	71	85	316	63.2	6.58	
	Setting Up	L	36	44	46.5	32.5	41.5				
		R	38	43	45.5	32.5	49.5				
		Total	74	87	92	65	91	409	81.8	8.52	<u>15.10</u>

* Forrester, J. D., and Taylor, J. F. A., <u>op.cit.</u>, pp. 33-35, Table VI.

Table IV continued

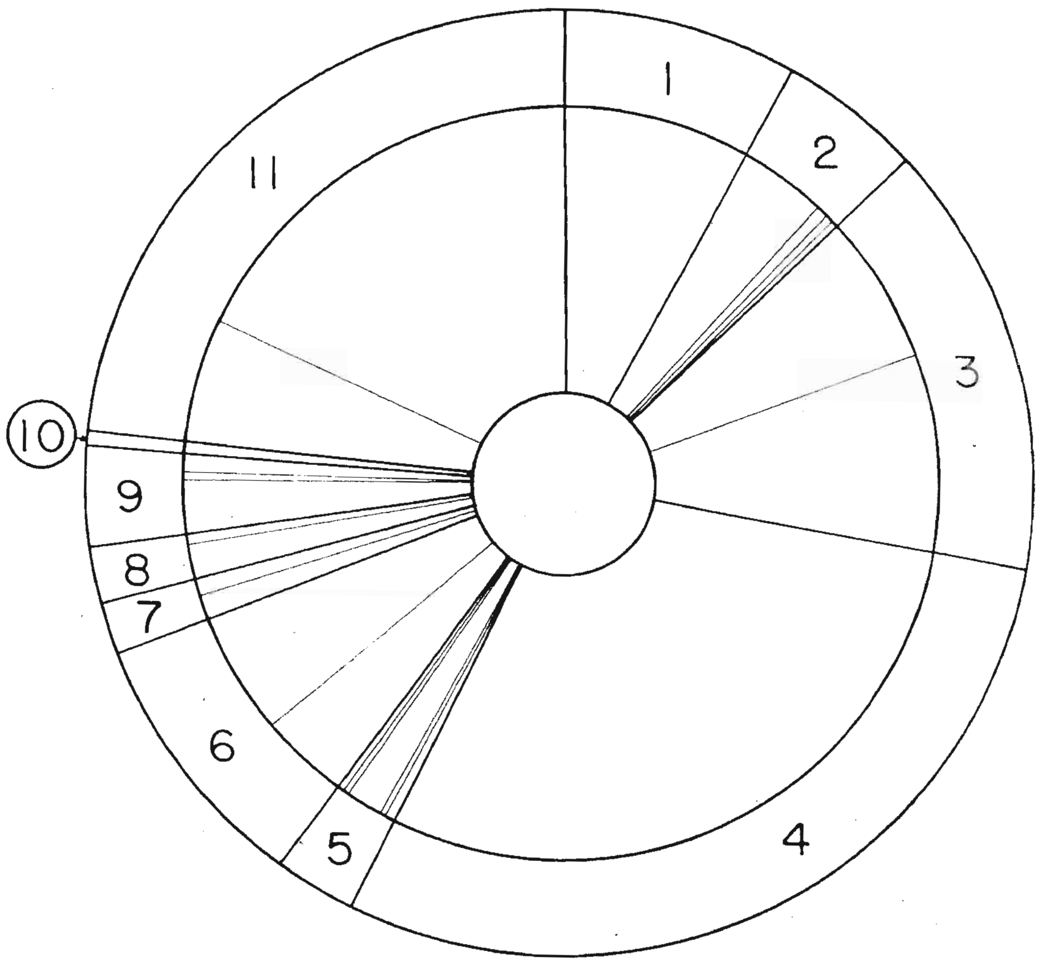
		Day	1	2	3	4	5	Total	Average per Shift	Percent	
4—DRILLING PRODUCTIVE ELEMENTS	Drilling & Changing	L	169	101	146.5	107.5	136				
		R	152.5	160.5	132	99.5	104				
		Total	321.5	261.5	278.5	207	240	1308.5	261.7	27.26	
	Helping Other Drill	L	15	12	15	10.5	2				
		R	7.5	9.5	24.5	9	6				
		Total	22.5	21.5	39.5	19.5	8	111	22.2	2.31	29.57
5—DRILLING, NON-PRODUCTIVE ELEMENTS	Clean Out Hole	L	0	6	2	0	3				
		R	0	6	2	0	3				
		Total	0	12	4	0	6	22	4.4	0.46	
	Blow Holes	L	9	4	22	2	0				
		R	5	4	17	5	8				
		Total	14	8	39	7	8	76	15.2	1.58	
	Wait on Blow Holes	L	0	0	0	3	8				
		R	4	0	1	0	0				
		Total	4	0	1	3	8	16	3.2	0.33	
	Collar Hole	L	0	2	9	0	0				
		R	5	0	2	0	0				
		Total	5	2	11	0	0	18	3.6	0.38	2.75
6—PRODUCTIVE DELAYS	Wait on Other Drill	L	13	28	42	0	7.5				
		R	17	23	18	16.5	15				
		Total	30	51	60	16.5	22.5	180	36.0	3.75	
	Wait on Extra Holes	L	12	53	0	28.5	21				
		R	27	10	37.5	20.5	39.5				
		Total	39	63	37.5	49	60.5	249	49.8	5.19	8.94
7—NON PRODUCTIVE DELAYS	Stuck Steel	L	0	0	0	13.5	15				
		R	0	10	7	0	0				
		Total	0	10	7	13.5	15	45.5	9.1	0.95	
	Wait on Stuck Steel	L	0	10	6	0	0				
		R	0	0	0	11	7				
		Total	0	10	6	11	7	34	6.8	0.71	1.66

Table IV continued

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
8—SUPPLY DELAYS	Collect Supplies	L	0	6	0	11	17				
		R	8	8	15	0	12				
		Total	8	14	15	11	29	77	15.4	1.60	
	Wait on Collect Supplies	L	0	6	0	0	0				
		R	0	4	0	0	0				
		Total	0	10	0	0	0	10	2.0	0.21	1.81
9—MAINTENANCE DELAYS	Hose Repairs	L	2	0	29	9	22				
		R	5	0	29	16	11				
		Total	7	0	58	25	33	123	24.6	2.56	
	Drill Maintenance & Repairs	L	2	0	0	0	3				
		R	4	0	0	1.5	3				
		Total	6	0	0	1.5	6	13.5	2.7	0.28	
	Repairs to Jumbo	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0	0	0	
	Oiling	L	7		1	4	2				
		R	2	2	7	2	9				
		Total	9	7	8	6	11	41	8.2	0.85	3.69
10—MISCELLANEOUS DELAYS	Machine Off Sash	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0	0	0	
	Blasting Damange	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0	0	0	
	Straighten Steel	L	0	4	0	0	0				
		R	0	0	0	0	0				
		Total	0	4	0	0	0	4	.8	0.8	
	Direct Powder Man	L	0	3	0	0	0				
		R	0	3	0	0	0				
		Total	0	6	0	0	0	6	1.2	0.13	0.21
	Powder Man Loading Holes	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0	0	0	

Table IV continued

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
II-IDLE TIME	Excessive Rest	L	26	42	17.5	27.5	20				
		R	25	42	18	32.5	11				
		Total	51	84	35.5	60	31	261.5	52.3	5.45	
	Wait at End of Shift	L	102	45	53	140	95				
		R	102	45	53	140	95				
		Total	204	90	106	280	190	870	174.0	18.14	<u>23.59</u>



TIME DISTRIBUTION CHART
LONG SASH JUMBO
2-MAN CREW

Plate VI

Table V - Drilling
Time Study Consolidation Sheet
Long Sash Jumbo - 3 Man Crew
All times given in minutes

		Day	1	2	3	4	Total	Average	Percent	
1-TRAVEL TIME		L D	41	40	36	31				
		H	41	40	35	31				
		R D	41	40	35	31	442	110.50	7.67	7.67
2-FACE PREPARATION	Muck Out	L D	10	3	8	0				
		H	14	5	2	5				
		R D	13	25	8	6	99	24.75	1.72	
	Wait on Muck Cut	L D	0	11	0	2				
		H	0	15	8	2				
		R D	0	3	0	2	43	10.75	.75	
	Face Inspection	L D	3	10	11	6				
		H	0	9	6	0				
		R D	3	10	11	6	75	18.75	1.30	
	Bar Down	L D	0	1	0	0				
		H	0	0	0	0				
		R D	0	0	0	0	1	.25	.02	
	Wait on Bar down	L D	0	0	0	0				
		H	0	0	0	0				
		R D	0	0	0	0	0	0	0	
	Hose down	L D	0	8	0	0				
		H	0	0	0	0				
		R D	0	0	0	0	8	2	.14	
	Wait on hose down	L D	0	0	0	5				
		H	0	8	0	5				
		R D	0	8	0	5	31	7.75	.54	
	Move Boulders	L D	0	6	0	0				
		H	0	6	8	0				
		R D	0	6	0	0	26	6.5	.45	4.92
3-DRILL PREPARATION	Move Jumbo	L D	30	38	33	23				
		H	32	36	33	23				
		R D	30	38	33	23	372	93.	6.46	
	Set Up	L D	43	34	30	33				
		H	43	20	27	28				
		R D	36	35	33	25	387	96.75	6.72	13.18

Table V continued

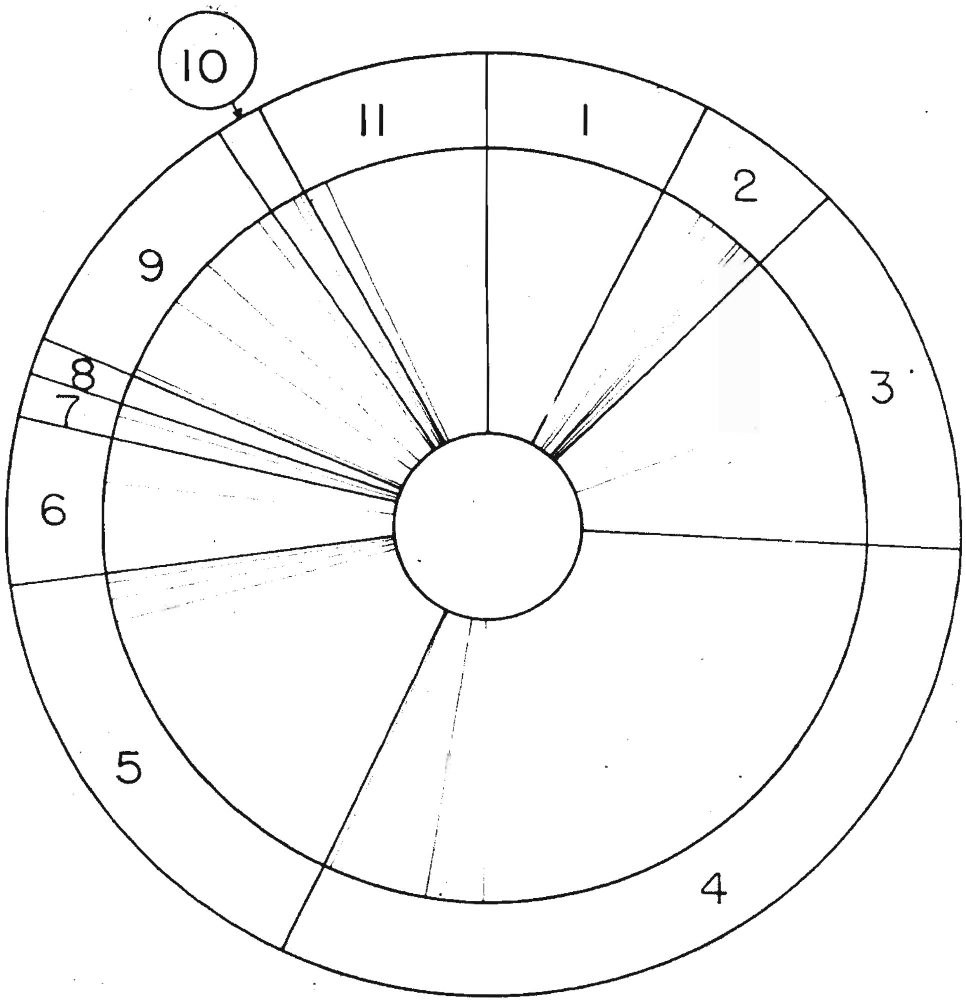
		Day	1	2	3	4	Total	Average per Shift	Percent	
4—DRILLING, PRODUCTIVE ELEMENTS	Drilling	L D	219	209	165	153				
		H	174	199	171	125				
		R D	0	0	0	0	1415	353.75	24.57	
	Changing Steel	L D	7	8	11	10				
		H	14	20	23	18				
		R D	7	12	16	6	152	38	2.64	
	Changing Bit	L D	16	16	10	6				
		H	42	60	31	32				
		R D	7	11	16	15	252	63.	4.37	
	Help Other Drilling	L D	0	0	0	0				
		H	0	0	0	0				
		R D	0	0	6	0	6	1.5	.10	31.68
5—DRILLING, NON-PRODUCTIVE ELEMENTS	Wait for Changing	L D	0	0	0	0				
		H	212	223	188	173				
		R D	0	0	0	0	796	199.	13.82	
	Clean Hole	L D	3	10	0	12				
		H	5	1	0	11				
		R D	17	2	0	5	56	14.	.97	
	Blow Hole	L D	3	3	3	12				
		H	3	0	0	3				
		R D	4	1	4	4	40	10.	.69	
	Wait on Blow Hole	L D	0	0	3	2				
		H	0	0	0	0				
		R D	0	1	1	1	8	2.	.14	
	Collaring	L D	0	0	5	3				
		H	1	0	5	0				
		R D	1	0	0	3	18	4.5	.31	15.93
6—PRODUCTIVE DELAYS	Wait on Other Drill	L D	0	0	0	0				
		H	45	18	13	0				
		R D	31	25	23	69	224	56	3.89	
	Wait on Extra Hole	L D	0	10	25	16				
		H	16	25	19	0				
		R D	0	0	0	0	111	27.75	1.93	5.82

Table V continued

		Day	1	2	3	4	Total	Average per Shift	Percent	
7—NON-PRODUCTIVE DELAYS	Stuck Steel	L D	0	18	3	22				
		H	1	2	0	9				
		R D	1	4	0	2	62	15.5	1.08	
	Wait on Stuck Steel	L D	0	3	0	0				
		H	0	4	0	0				
		R D	0	0	0	11	18	4.5	.31	1.39
8—SUPPLY DELAYS	Collect Supplies	L D	8	4	3	0				
		H	15	10	3	8				
		R D	7	4	7	0	69	17.25	1.19	
	Wait on Collect Supplies	L D	0	0	4	0				
		H	0	0	0	0				
		R D	0	0	0	0	4	1	.07	1.26
9—MAINTENANCE DELAYS	Hose Repairs	L D	0	0	0	5				
		H	0	0	0	0				
		R D	0	0	0	11	16	4	.28	
	Drill Main. & Repairs	L D	2	0	27	70				
		H	0	0	27	44				
		R D	13	0	8	9	200	50	3.47	
	Wait on Drill Main. & Repairs	L D	3	0	8	0				
		H	12	0	0	28				
		R D	0	0	16	44	111	27.75	1.93	
	Repairs to Jumbo	L D	0	3	52	0				
		H	0	3	52	0				
		R D	0	3	52	0	165	41.25	2.86	
	Oiling	L D	2	6	0	6				
		H	2	1	0	0				
		R D	7	3	9	7	43	10.75	.75	9.29
10—MISCELLANEOUS DELAYS	Recovering Steel	L D	15	0	0	0				
		H	12	0	0	0				
		R D	37	0	0	0	64	16.	1.11	
	Straighten Steel	L D	0	0	3	0				
		H	0	0	0	0				
		R D	6	0	0	0	9	2.25	.16	

Table V continued

Category	Item		Day 1	2	3	4	Total	Average per Shift	Percent	
10-continued	Wait for Power Cable to be moved forward	L D	0	0	0	4				
		H	0	0	0	4				
		R D	0	0	0	4	12	3.	.21	1.48
11-IDLE TIME	Excessive Rest	L D	0	3	3	8				
		H	0	3	3	15				
		R D	0	3	3	15	56	14.	.97	
	Wait at End of Shift	L D	30	18	24	51				
		H	30	18	24	51				
		R D	30	18	24	51	369	92.25	6.41	7.38



TIME DISTRIBUTION CHART

LONG SASH JUMBO

3-MAN CREW

Plate VII

Table VI Drilling*
Time Study Consolidation Sheet
Post mounted drill — 2 man crew
All times given in minutes

				Percent	
1-TRAVEL TIME		D	48		
		H	48		
		Total	96	10.00	10.00
2-FACE PREPARATION	Wait on Muck Out	D	28		
		H	28		
		Total	56	5.83	
	Face Inspection	D	10		
		H	10		
		Total	20	2.08	
	Barring Down	D	0		
		H	0		
		Total	0	0	
	Wait on Barring Down	D	0		
		H	0		
		Total	0	0	
	Hose down	D	8		
		H	0		
		Total	8	0.83	
	Wait on Hose Down	D	0		
		H	8		
		Total	8	0.83	9.57
3-DRILL PRE-PARATION	Erecting Post	D	44		
		H	44		
		Total	88	9.17	
	Setting Up	D	70		
		H	70		
		Total	140	14.58	23.75
4-DRILLING PRODUCTIVE ELEMENTS	Drilling & Changing	D	179		
		Total	179	18.65	
	Changing	H	61		
		Total	61	6.35	25.00

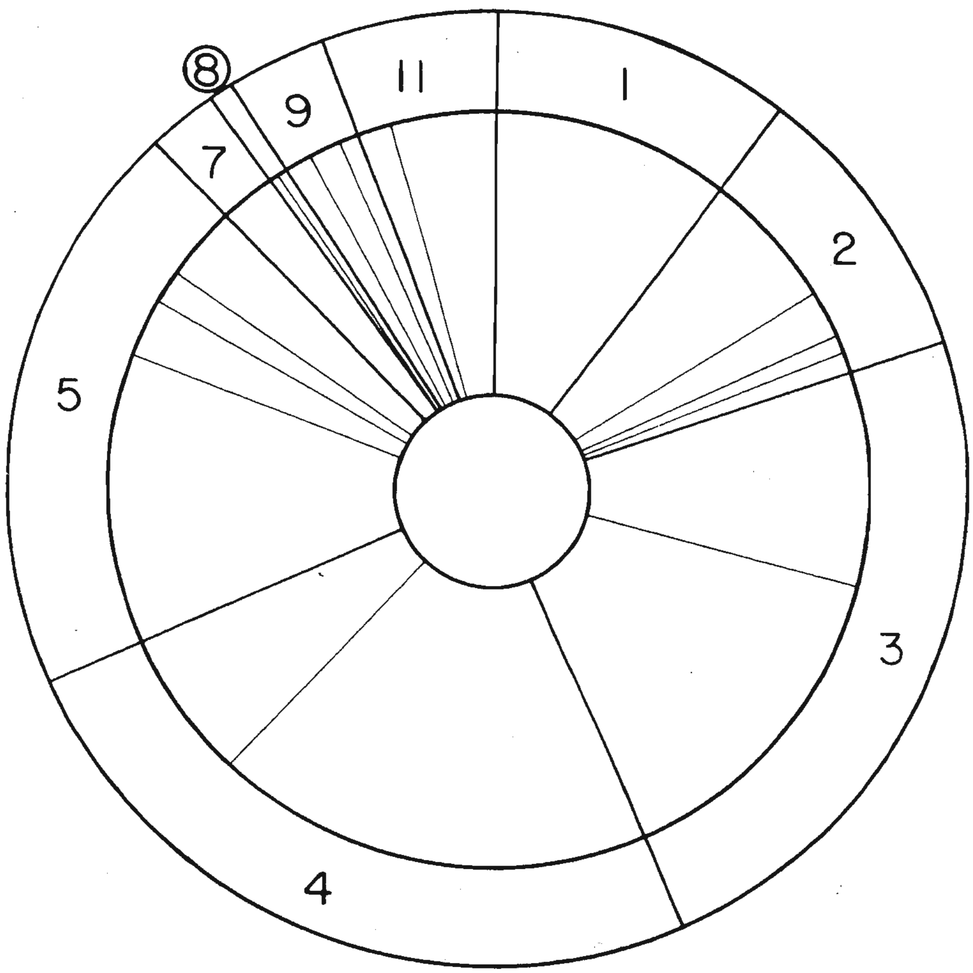
* Forrester, J. D., and Taylor, J. F. A., op.cit. p. 28, Table IV

Table VI continued

				Percent	
5—DRILLING, NON-PRODUCTIVE ELEMENTS	Wait for Changing	H	118		
		Total	118	12.29	
	Clean Out Hole	D	12		
		H	12		
		Total	24	2.50	
	Blow Holes	D	6		
		H	6		
		Total	12	1.25	
	Wait on Blow Holes	D	0		
		H	0		
		Total	0	0	
	Collar Hole	D	15		
		H	15		
		Total	30	3.13	19.17
7—NON-PRODUCTIVE DELAYS	Stuck Steel	D	12		
		H	12		
		Total	24	2.56	2.56
8—SUPPLY DELAYS	Collect Supplies	D	0		
		H	4		
		Total	4	0.42	
	Wait on Collect Supplies	D	4		
		H	0		
		Total	4	0.42	0.84
9—MAINTENANCE DELAYS	Hose Repairs	D	5		
		H	5		
		Total	10	1.04	
	Drill Maintenance	D	6		
		H	6		
		Total	12	1.25	
	Oiling	D	4		
		H	4		
		Total	8	0.83	3.12
10—MISCELLANEOUS DELAYS	None occurred				

Table VI continued

				Percent	
11-IDLE TIME	Excessive Rest	D	7		
		H	7		
		Total	14	1.46	
	Wait at End of Shift	D	22		
		H	22		
		Total	44	4.58	6.04



TIME DISTRIBUTION CHART
POST-MOUNTED DRILL
2-MAN CREW

Plate VIII

Table VII - Drilling
Time Study Consolidation Sheet
Post Mounted Drills - 3 Man Crew
All time given in minutes

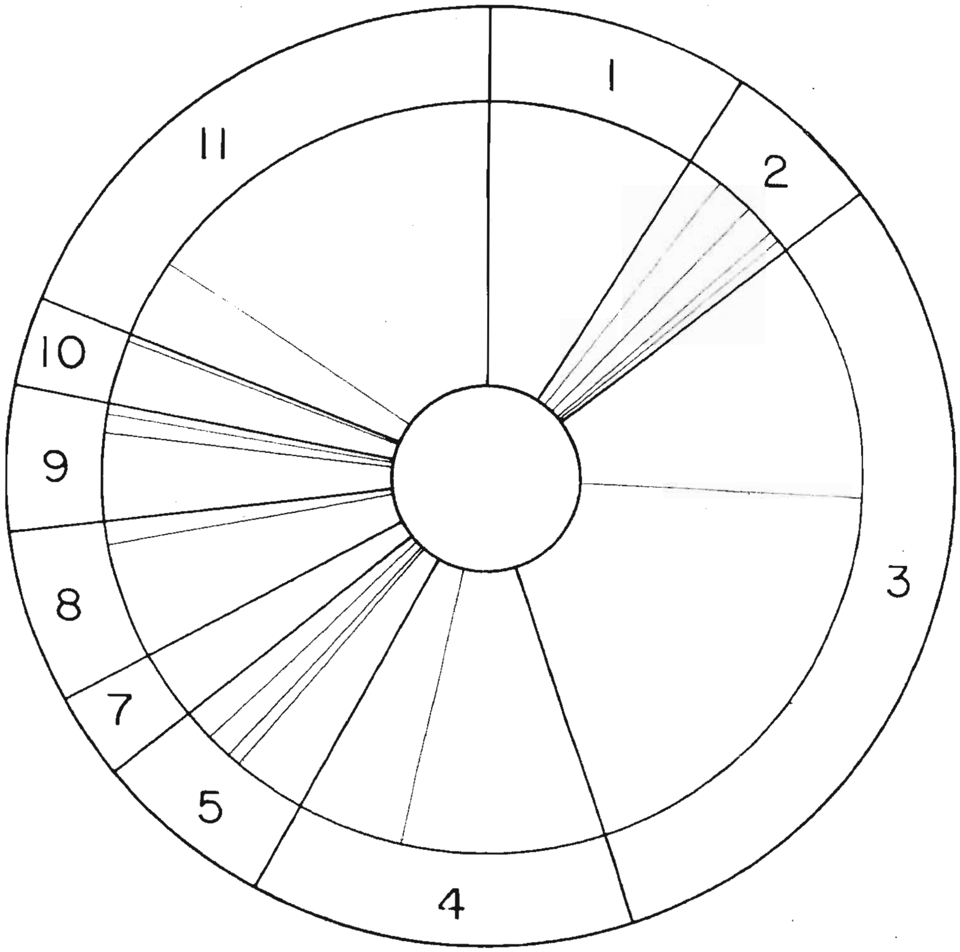
		Day	1	2	Total	Average per Shift	Percent	
1-TRAVEL TIME		L D	44	42				
		H	44	42				
		R D	44	42	258	129	8.96	8.96
2-FACE PREPARATION	Muck out	L D	0	14				
		H	3	0				
		R D	6	24	47	23.5	1.63	
	Wait on Muck Out	L D	0	0				
		H	0	0				
		R D	0	0	0	0	0	
	Face Inspection	L D	7	11				
		H	4	9				
		R D	4	9	44	22	1.53	
	Barring down	L D	5	0				
		H	0	0				
		R D	0	0	5	2.5	0. 17	
	Wait on Barring down	L D	6	7				
		H	6	7				
		R D	6	7	39	19.5	1.35	
	Hose down	L D	0	7				
		H	2	0				
		R D	0	0	9	4.5	.31	
	Wait on Hose down	L D	0	0				
		H	0	7				
		R D	0	0	7	3.5	.24	
	Moving Boulders	L D	0	0				
		H	0	0				
		R D	0	0	0	0	0	5.23
3-DRILL PREPARATION	Erecting Post	L D	61	58				
		H	41	55				
		R D	56	57	328	164	11.39	
	Setting Up	L D	85	92				
		H	85	98				
		R D	105	82	547	273.5	18.99	30.38

Table VII continued

Category	Element	Day	1	2	Total	Average per Shift	Percent	
4-DRILLING PRODUCTIVE ELEMENTS	Drilling	L D	73	64				
		H	54	58				
		R D	0	0	249	124.5	8.65	
	Changing Steel	L D	21	20				
		H	26	31				
		R D	19	17	134	67	4.65	
	Help Other Drilling	L D	0	0				
		H	0	0				
		R D	0	0	0	0	0	13.30
5-DRILLING, NON PRODUCTIVE ELEMENTS	Wait for Changing	L D	0	0				
		H	54	38				
		R D	0	0	92	46	3.19	
	Clean Out Hole	L D	5	0				
		H	3	0				
		R D	3	3	14	7	.49	
	Blow Holes	L D	4	6				
		H	4	7				
		R D	2	10	33	16.5	1.15	
	Wait on Blow holes	L D	0	0				
		H	0	0				
		R D	0	0	0	0	0	
	Collar Hole	L D	12	0				
		H	14	3				
		R D	2	3	34	17	1.18	6.01
7-NON-PRODUCTIVE DELAYS	Stuck Steel	L D	17	20				
		H	8	14				
		R D	12	17	88	44	3.06	3.06
8-SUPPLY DELAYS	Collect Supplies	L D	6	5				
		H	81	24				
		R D	25	3	144	72	5.00	
	Wait on Collect Supplies	L D	16	0				
		H	0	0				
		R D	16	0	32	16	1.11	6.11

Table VII continued

		Day	1	2	Total	Average per Shift	Percent	
9—MAINTENANCE DELAYS	Hose Repairs	L D	4	25				
		H	4	43				
		R D	10	25	111	55.5	3.85	
	Drill Maintenance & Repairs	L D	7	3				
		H	0	0				
		R D	11	0	21	10.5	.73	
	Wait on Drill Main. & Repairs	L D	0	0				
		H	0	0				
		R D	0	0	0	0	0	
	Oiling	L D	4	0				
		H	0	0				
		R D	3	3	10	5	.35	4.93
10—MISCELLANEOUS DELAYS	Wait for Water to be Pumped out	L D	0	22				
		H	0	33				
		R D	0	27	82	41	2.85	
	Recovering Steel	L D	0	0				
		H	0	0				
		R D	0	7	7	3.5	.24	3.09
11—IDLE TIME	Excessive Rest	L D	29	9				
		H	27	5				
		R D	22	11	103	51.5	3.58	
	Wait at End of Shift	L D	74	75				
		H	74	64				
		R D	80	75	442	221	15.35	18.93



TIME DISTRIBUTION CHART

TWO POST-MOUNTED DRILLS

3-MAN CREW

Plate IX

Table VIII

Move, Set Up, and Drilling Data for a 2-man crew for Short Sash Jumbos

		Stope	Breast	Roof	Total
DRILLING	Type of Hole	Stope	Breast	Roof	Total
	Driller's Time—mins.	519	302	301	1122
	Feet drilled	213.5	150.5	153.5	517.5
	Feet drilled per drill shift				66.2
	No. of holes	24	16	16	56
	No. of holes per drill shift				7.0
	Drilling Speed—ft./min.	.41	.49	.51	.47
	Ave. depth-ft.	8.9	9.4	9.6	9.2
	Ave. time per hole—mins.	21.6	19.0	18.8	20.3
	No. of steels	88	63	66	217
	Ave. steels per hole	3.7	3.9	4.1	3.9
	Feet drilled per steel	2.42	2.38	2.32	2.38
SETTING UP	Total Time Setting Up—mins.				326
	No. of holes				56
	Ave. time per hole				5.8
MOVE JUMBO	Total Time Moving Jumbo				158
	No. of Moves				17
	Ave. time per move				9.3

Table IX

Move, Set Up, and Drilling Data for a 3-man crew for Short Sash Jumbos

	Type of Hole	Stope	Breast	Roof	Total
DRILLING	Driller's Time-mins.	177	328	186	691
	Feet Drilled	115.0	188.5	137.5	441.0
	Feet drilled per drill shift				73.5
	No. of holes	11	17	16	44
	No. of holes per drill shift				7.3
	Drilling Speed—ft./min.	.65	.57	.73	.65
	Ave. depth—ft.	10.4	11.0	8.5	10.0
	Ave. time per hole—mins.	16.1	19.3	11.6	15.7
	No. of steels	45	73	54	172
	Ave. steels per hole	4.1	4.3	3.7	4.0
	Feet drilled per steel	2.55	2.58	2.54	2.56
SETTING UP	Total Time Setting Up—mins.				398
	No. of holes				44
	Ave. time per hole				9.05
MOVING JUMBO	Total Time Moving Jumbo				124
	No. of Moves				12
	Ave. time per move				10.0

Table X*

Move, Set Up, and Drilling Data for 4 man crew for Short Sash Jumbos

	Type of Hole	Stope	Breast	Roof	Total
DRILLING	Driller's Time--mins.	455	389	557	1401
	Feet drilled	241	223	240.5	704.5
	Feet drilled per drill shift				70.4
	No. of holes	31	29	36	96
	No. of holes per drill shift				9.6
	Drilling Speed--ft./min.	0.53	0.57	0.43	0.40
	Ave. depth--ft.	7.8	7.7	6.7	7.3
	Ave. time per hole--mins.	14.7	13.4	15.8	14.6
	No. of Steels	111	103	116	330
	Ave. steels/hole	3.6	3.6	3.2	3.4
	Feet drilled/steel	2.17	2.16	2.08	2.4
SETTING UP	Total Time Setting Up--mins.	317	223	267	807
	No. of holes	31	29	36	96
	Ave. time per hole	10.2	7.7	7.4	8.4
MOVE JUMBO	Total Time Moving Jumbo--mins.				432
	No. of Moves				21
	Ave. time per move				20.6

* Forrester, J. D. and Taylor, J. F. A., op. cit., p. 39

Table XIX*

Move, Set-Up, and Drilling Data for 2 Man Crew for Long Sash Jumbos

	Type of Hole	Stope	Breast	Roof	Total
DRILLING	Driller's Time—mins.	423.5	422	463	1308.5
	Feet drilled	296.5	241.5	308.5	846.5
	Feet drilled per drill shift				84.6
	No. of holes	29	25	35	89
	No. of holes per drill shift				8.9
	Drilling Speed—ft./min.	0.70	0.57	0.67	0.65
	Ave. depth—ft.	10.2	9.6	8.8	9.5
	Ave. time per hole—min.	14.6	16.9	13.2	14.7
	No. of steels	52	45	62	159
	Ave. steels/hole	1.79	1.80	1.77	1.79
	Feet drilled/steel	5.7	5.4	5.0	5.3
SETTING UP	Total Time Setting Up—mins.	186.5	86.5	136	409
	No. of Holes	29	25	35	89
	Ave. time per hole	6.4	3.5	3.9	4.6
MOVE JUMBO	Total Time Moving Jumbo—mins.				316
	No. of moves				19
	Ave. time per move				16.6

* Forrester, J. D. and Taylor, J. F. A., op.cit., p. 40

Table XII

Move, Set Up, and Drilling Data for a 3-man crew for Long Sash Jumbos

	Type of Hole	Stope	Breast	Roof	Total
DRILLING	Driller's Time—mins.	490	436	489	1415
	Feet drilled	262.0	220.0	258.5	740.5
	Feet drilled/drill shift				92.5
	No. of holes	28	23	30	81
	No. of holes/drill shift				10.1
	Drilling Speed—ft./min.	.53	.50	.53	.52
	Ave. depth—ft.	9.3	9.6	8.6	9.2
	Ave. time per hole—mins.	17.5	18.9	16.3	17.5
	No. of steels	46	38	50	134
	Ave. steels/hole	1.64	1.65	1.66	1.65
	Feet drilled/steel	5.7	5.7	5.1	5.5
SETTING UP	Total Time Setting Up—mins.				387
	No. of holes				81
	Ave. time per hole				4.8
MOVE JUMBO	Total time Moving Jumbo				372
	No. of Moves				17
	Ave. time per move				21.8

Table XIII

Move, Set Up, and Drilling Data for 2 man crew for Hand-feed, Post-mounted Drills

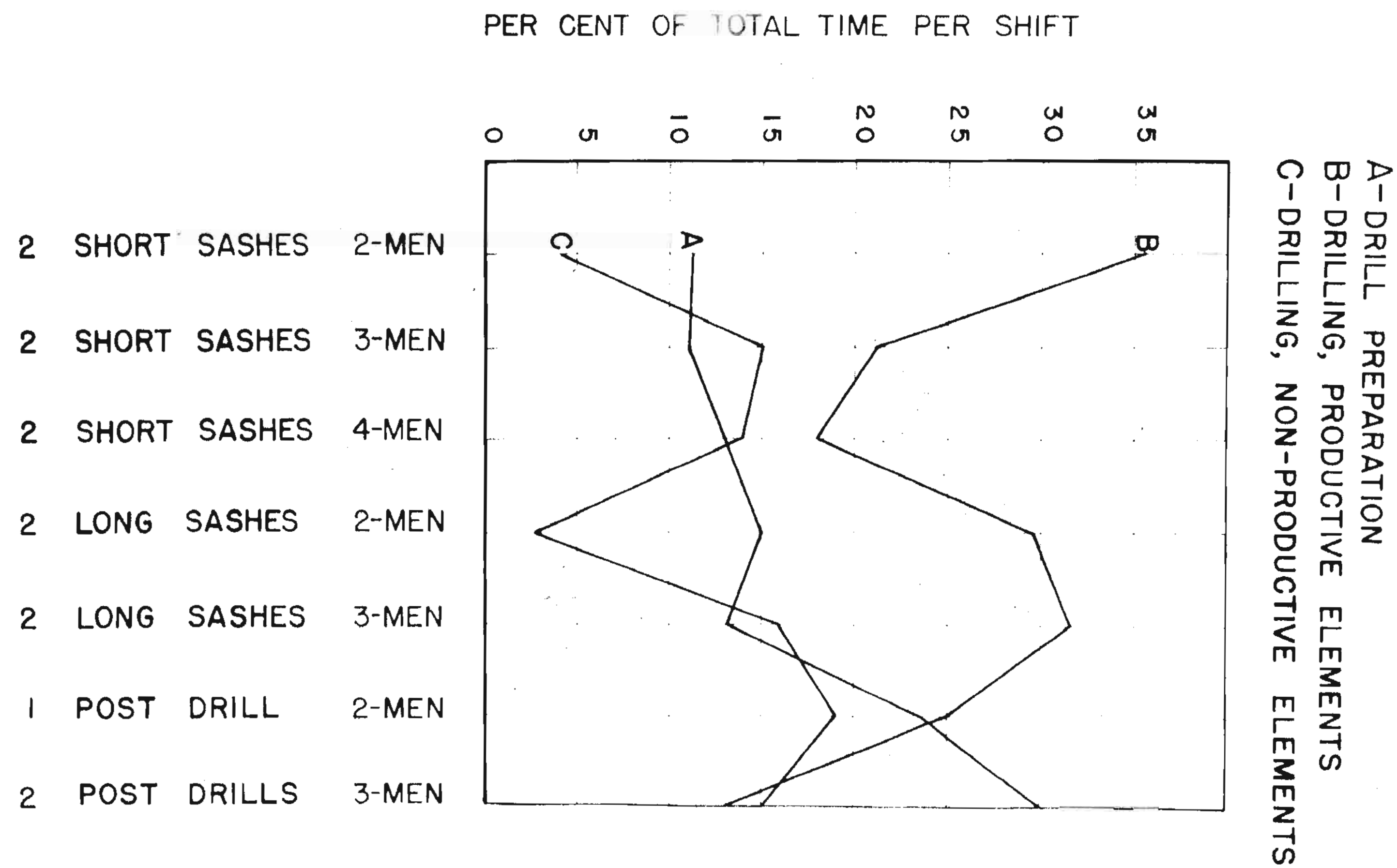
	Type of Hole	Stope	Breast	Roof	Total
DRILLING	Driller's Time—mins.	65.5	138	98.5	302
	Feet drilled	30	53.5	40	123.5
	Feet drilled per drill shift				61.7
	No. of holes	3	7	5	15
	No. of holes per drill shift				7.5
	Drilling Speed—ft./min.	0.46	0.39	0.41	0.41
	Ave. depth—ft.	10	7.6	8.0	8.2
	Ave. time per hole—mins.	21.8	19.7	19.7	20.1
	No. of steels	15	26	20	61
	Ave. steels/hole	5.0	3.7	4.0	4.1
	Feet drilled/steel	2.00	2.06	2.00	2.02
SETTING UP	Total Time Setting Up—mins.	48	102	88	238
	No. of holes	3	7	5	15
	Ave. time per hole	16.0	14.6	17.6	15.9
MOVE—A	Total Time Erecting Post—mins.				198
	No. of times Post erected				3
	Ave. time				66.0
MOVE—B	Total Time Erecting Tripod—mins.				116.
	No. of times tripod erected				3
	Ave. time				38.7

* Forrester, J. D., and Taylor, J. F. A., *op.cit.*, p. 39

Table XIV

Move, Set Up, and Drilling Data for a 3-man crew for Two Hand-fed Post-mounted Drills

	Type of Hole	Stope	Breast	Roof	Total
DRILLING	Driller's time--mins.	85	89	75	249
	Feet drilled	49.5	56.5	49.5	155.5
	Feet drilled/drill shift				38.8
	No. of holes	7	9	7	23
	No. of holes/drill shift				5.7
	Drilling Speed--ft./mins.	.58	.63	.66	.62
	Ave. depth--ft.	7.0	6.3	7.0	6.7
	No. of Steels	21	21	23	65
	Ave. steels per hole	3	2.3	3.3	2.8
	Feet drilled per steel	2.36	2.69	2.15	
SETTING UP	Total Time Setting Up				547
	No. of holes				23
	Ave. time per hole				23.8
ERECTING POST	Total Time Erecting Post				328
	No. times post erected				4
	Ave. time				82



TIME GRAPH OF DRILLING

Plate X

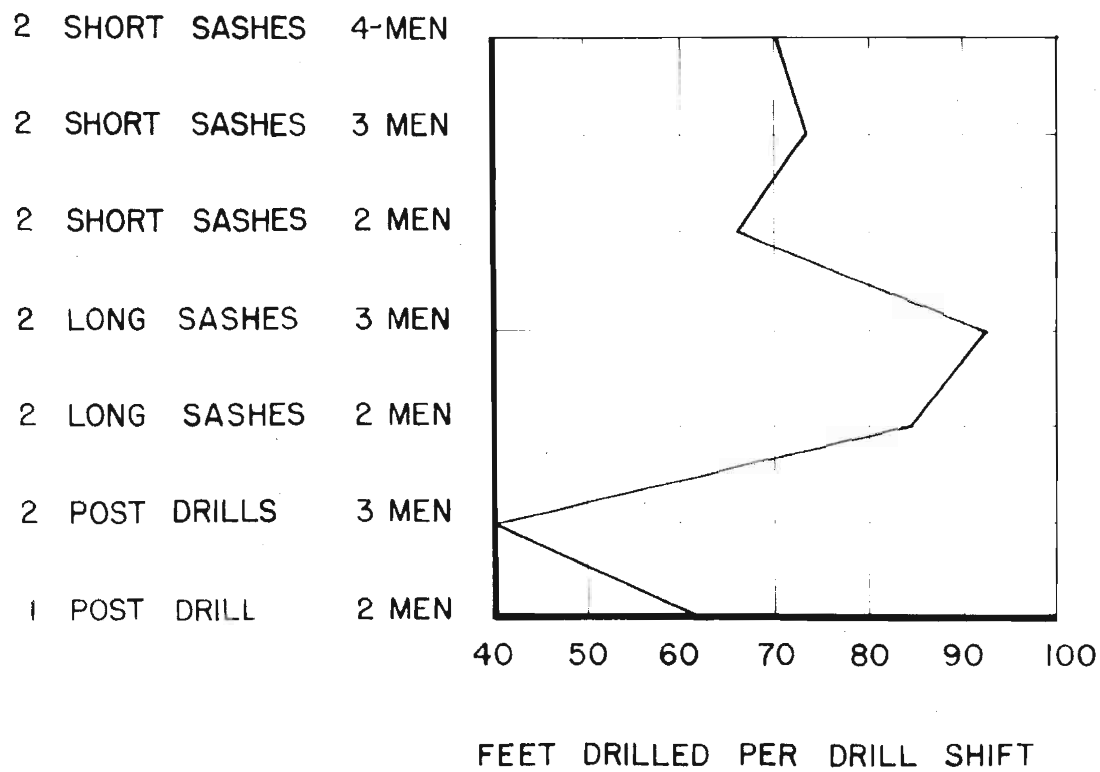

2 SHORT SASHES 4-MEN
2 SHORT SASHES 3 MEN
2 SHORT SASHES 2 MEN
2 LONG SASHES 3 MEN
2 LONG SASHES 2 MEN
2 POST DRILLS 3 MEN
1 POST DRILL 2 MEN
40 50 60 70 80 90 100
FEET DRILLED PER DRILL SHIFT

Plate XI

1. Travel Time. Travel time is directly dependent upon the distance from the shaft to the face to be drilled and is not affected by the methods of drilling.

2. Face Preparation. Some of the elements of face preparation, namely "muck out", "wait on muck out", "barring down", "wait on bar down", and "moving boulders" are not directly dependent upon the methods of drilling or upon the size of the drilling crew, instead, they may occur because other phases of mining, such as scraping and barring down, have not been thoroughly completed. Scrapers may not clean the face adequately. The roof trimmers, in performing their task at the beginning of the shift, may block the face. Whatever the cause, the obstruent material must be removed before productive drilling can proceed.

Tables 3 and 6 show that the short sash operation with three men and the post-mounted drill operation with two men utilized an average of 10.49 and 9.57 percent of a shift respectively in face preparation. These times consumed are nearly twice as much as any other similar operation and the cause may be largely attributed to the elements "muck out" and "wait on muck out".

Although the number of men in the drilling crew was variable, the general uniformity of the time consumed indicates that an addition of personnel to the standard drilling crew does not result in a marked saving either in time or labor. Minor fluctuations in categories may be charged to other mining operations as mentioned above. Face preparation is, therefore, a partial measure of the efficiency of these other mining phases and is not directly dependent upon either the size of the drilling crew or the method of drilling.

Drill Preparation.

The time consumed in moving the jumbo from one face to the next depends not only upon the distance between the two faces but also upon the speed of the jumbos. At one mine the short sash jumbo travelled at a rate of 3 miles per hour while at another mine the speed of the long sash jumbo was 0.5 miles per hour. Thus, if the jumbos are stationed very far from the face the effect of their speed will be noticeable in the elements "moving jumbo". However, as it is only necessary for the jumbos to be moved from their station to the working place at the beginning of the shift and back again at the end of the shift, and as the distances were in all cases comparatively short, the time consumed during their traveling was not so excessive as to greatly influence the "moving jumbo" element with the exception of the long sash jumbos (Tables 4 and 5).

Tables 1, 2, 3, 4, and 5 show that in all cases the short sash jumbos consumed less per cent time per shift than the long sash jumbos in moving. This may be attributed to not only the jumbo's speed but also to the fact that the hoses are more readily dragged from face to face with the aid of one or two extra men, as the case may be. It must be remembered that the element "moving jumbo" includes both the time taken in moving the machine from its station to the working area and the time consumed in moving from face to face.

The post-mounted drill operated by two men utilized less per cent time per shift in post erection than the two post-mounted drills operated by three men (Tables 6, 7). It is to be expected that the two post-mounted drills operated by three men would consume more time because more work per man is required to erect the posts.

Tables 1, 2, 3, 4, and 5 show that the per cent time per shift consumed by jumbos in "setting up" are nearly similar to one another. This is to be expected since the operations necessary in setting up are the same in all types of jumbo drilling. Thus because of the similarity in per cent time consumption it is gathered that the addition of men to the drilling crew does not directly aid in the element "setting up".

Tables 6 and 7 show that the per cent time per shift used by three men on two posts in setting up is more than that used by two men and one post. As in the post mounted drill operation of "erecting post", a parallel situation occurs in that more work per man is necessary for three men to set up two drills.

Plate 10, line A, which is a graph of drill preparation and the per cent time consumed per shift for the different man-jumbo crews and the post-mounted drill crews, summarizes the elements of drill preparation. Although the short sash jumbo with a three man crew shows a slightly lower percentage of time used per shift (12.60 per cent and 12.09 per cent) it is not considered to be sufficient to warrant the service of an extra man. The long sash jumbo operation with two and three men may be considered in a like manner, that is, the long sash jumbo operated by two men is more efficient in face preparation than the three man crew although the latter utilizes less time per man per shift.

The post-mounted drill operated by two men and the two post-mounted drills operated by three men have time percentage per shift items of 23.75 per cent and 30.38 per cent respectively (Tables 6, and 7). The latter operation necessitates more work per man than does the former, consequently it is to be expected that the post-mounted drill operated by two men would use less time per man per shift.

In summary it may be stated that the short sash jumbo, the long sash jumbo, and the post-mounted drill operation are most efficient with respect to drill preparation when operated by two-man crews.

Drilling. Productive Elements.

Although the drilling rates of similar drills are constant, that is, will not vary markedly, the average rate of the short and long sash machines is .54 and .59, respectively. These differences in drilling rates are to be expected because the long sash drills have a definite advantage in that they do not require frequent changing of steel, viz, the short sash machines operated by 2, 3, and 4 men drilled 2.38, 2.56, and 2.14 feet per steel, respectively, whereas the long sash machines operated by 2 and 3 men drilled 5.3 and 5.5 feet per steel. (See tables 8-12)

The post-mounted drill operated by 2 men and the two post mounted drills operated by three men averaged .51 feet drilled per minute. The drilling rate of the latter is .62 feet per minute but, this relatively large drilling rate may be attributed to the ~~face~~ fact that the average depth of hole was 6.7 feet as compared to the former operation which averaged 8.2 feet. (See tables 13 and 14.)

It must be emphasized that in comparing drilling rates there are a number of factors that must be taken into consideration, namely, the character of the ground, the depth of hole, the sharpness of the bit and the number of steels used. It was a combination of the above factors that was responsible for the comparatively high drilling rate of the two post-mounted drill operation.

The effect of variable size crews on jumbos with regard to feet drilled per drill shift is pictured in Plate 11, namely, the short sash operated by 2, 3, and 4 men accomplished 66.2, 73.5 and 70.4 feet per drill shift, respectively, as compared to 84.6 and 92.5 feet per drill shift by the long sash drills operated by 2 and 3 men, respectively.

The footage drilled per drill shift by the post-mounted drill with a 2-man crew and the two post-mounted drills operated by a 3-man crew is 61.7 and 31.8, respectively. This decrease in feet drilled from the former to the latter is to be expected because the footage drilled per shift partially depends on the amount of time available to drill. In the latter operation of two post-mounted drills operated by a 3-man crew a much greater burden per man was experienced in each of the occupations and thus less time was available to perform actual drilling.

The total time consumed per shift in changing steel is partially dependent upon the depth of holes drilled and the number of steels used. The element "changing steel" does not vary greatly from one type of drilling to another and from this similarity it is gathered that the usefulness of helpers in this occupation is not as great as might be expected. Although the short sash drills require more frequent changes of steel the time consumed in such an occupation is relatively small and seldom is greater than 1 minute.

The long sash drill jumbo, operated by a 3-man crew, was worked in ground that was extremely hard and consequently frequent replacement of the dulled bits was necessary. "Changing bits" is distinct from that of "changing steel" in that the same steel is used with two or three new bits.

On jumbo crews consisting of two men, the drillers aid one another in starting and/or collaring holes. This mutual aid naturally causes a delay in the drilling procedure but, the members of the drilling crews have become so proficient in the use of the jumbos that the time consumed has been reduced to a minimum. However, Tables 1, 2, 4, and 5 show that short sash and the long sash drills with 2-man crews utilized 1.48 and 2.31 per cent of the shift in helping the other drilling whereas the same operations with 3-man crews utilized only .09 and .10 per cent of the shift, respectively.

The effect of different size jumbo crews on the productive elements of drilling is not readily obtained from the total per cent of time consumed in a shift (Plate 10, line B), but rather from the actual feet drilled per shift (Plate 11), as stated before. Although the short sash drill operation with a 3-man crew obtained more footage per shift than either the short sash drills with 2 or 4-man crews, it does not necessarily mean that the former is both more efficient and economical than the latter. In some cases it may be desirable or necessary to sacrifice a little footage for economy.

Drilling, Non-Productive Elements.

"Wait for changing" is applicable only to those drilling operations in which the jumbo crews consist of more than two men. Both the short sash and long sash jumbos operated by two drillers do not have any helpers and consequently these phases of drilling lack the above element.

Although the helpers aid the drillers in changing steel and thus make available more time in which to drill it is to be expected that there will be numerous occasions during the drilling cycle in which they will be idle, that is, waiting for the next change of steel. Tables 2, 3, and 5 show that the short sash jumbo operated by a 3 and

4-man crew and the long sash jumbo operated by a 3-man crew utilized 9.19, 10.84, and 13.82 per cent of the total time per shift, respectively, in waiting for the next change of steel. It is apparent that the element "wait for changing" increases as the size of the drilling crew increases. The long sash jumbo is capable of drilling deeper holes without changing steel than are the short sash jumbos and consequently the time during which the helper waits for the next change of steel will be greater than that of the short sash jumbos. (See Tables 2, 3, and 5.)

As has been stated before, the two post-mounted drill operation necessitated much more work per man than did the single post-mounted operation, thus it is to be expected that there would be less time during which the helper is waiting for the next change of steel. This is readily seen in Tables 6 and 7 which show that the former operation utilized 12.29 per cent of the shift in waiting for changing steel whereas the latter operation only used 3.19 per cent of the shift.

All other occupations listed under this category are not directly influenced by the number of personnel in the drilling crew, but may be the result of difficulties that arise in the drilling cycle, namely; caved holes and difficulty in collaring.

The elements of "Drilling, Non-Productive Elements" are graphically pictured in Plate 10 from which it is evident that jumbos with crews consisting of 3 or 4-man expend more time in the non-productive phases of drilling than do the jumbos with 2-man crews. This is especially apparent and noticeable with the long sash jumbo operated by a 3-man crew, namely, the long sash jumbos with 2 and 3-man crews utilized 2.75 and 15.93 per cent of the total time per shift. Thus, it is apparent that the jumbos with the 2-man crews consume less time in the non-productive phases of drilling and so may be considered more efficient than the jumbos with larger crews. It is also evident that where ever the element "wait for charging" occurs, it dominates the category.

Tables 6 and 7 and Plate 10 show that the additional amount of work required per man to operate two post-mounted drills with three men has materially reduced both the element "wait for charging" and the whole category of "Drilling, Non-Productive Elements".

Productive Delays

The elements of this category, namely; "Wait on other drill" and "wait on extra holes" are important items because they directly retard the maximum drilling progress of the jumbos. The former element results not only from holes of different depths being drilled but also because the drilling rates of the drills are not equal. The latter element occurs from irregularities either in the face, roof, or floor that must be corrected so that the two or three drills mounted on the jumbo, as the case may be, may operate as a unit.

Post-mounted drills are not subject to these delays as each machine operates as a separate unit.

The presence or absence of helpers in the drilling crew does not directly effect either of the elements of Productive Delays other than to increase the total per cent of time consumed in waiting during the shift. (See Tables 1-5).

Non-Productive Delays

"Stuck steel" is common to all classes of drilling whereas "wait on stuck steel" occurs only with the jumbos and then only when one drill on the jumbo is prevented from productive drilling or starting the next hole.

Although the helpers may aid in overcoming the delay caused by stuck steel and thereby increase the total time in which the drill may operate, the general effect of their presence is to increase the per cent of total time per shift either in aiding or in waiting upon stuck steel. (See Tables 1-5.) Thus it is apparent that the effect of variable crews applied to non-productive delays is negative, that is, any combination of drilling crews does not directly aid in lessening the delays of this category.

Supply Delays

Occasions arise during the drilling cycle when supplies are needed so that the drilling may proceed, and in such cases helpers, whenever present in the crew, aid the operation by collecting the necessary materials. Time consumed in collecting the supplies is charged to this category under the element "collect supplies". However, at the same time it frequently happens that the driller may not be able to do productive work and thus the time consumed by him in waiting is also charged to this category under the element "wait on collect supplies". Hence for jumbo drill crews consisting of more than one man per drill, both the driller's wait and the helpers collection of supplies are expended in supply delays. This is not the case when no helpers are used as the driller must collect his own supplies and only such time so expended by him is recorded in this classification. Therefore, in operations where a helper is a part of the unit, twice as much time is designated to this category as for those crews where no helper is present. Further, occasions also arise, especially in jumbo crews of 2-men, when one driller, absent from his drill because of supply demands, may prevent the other driller from starting work on the next hole.

From the above discussion it is to be gathered that variable size jumbo crews do not have a marked effect upon the delays caused by supply requirements, and although helpers are beneficial to procure the supplies, the additional time made available for productive drilling has not been greatly increased.

Maintenance Delays

The elements included under this heading are sporadic in their occurrence with the exception of oiling which is a routine activity. Although these elements occur during the drilling cycle and thus disrupt the progress of the drills there is no apparent effect on the category "maintenance delays" brought about by different crew ratios except to either increase the time consumption in repair or to increase the elements of waiting upon the said repair.

Miscellaneous Delays

All elements under this heading are both unpredictable and noncyclic, however, they may either directly or indirectly effect the footage drilled per shift. That is, if a steel breaks in a hole that is nearly completed and that steel is recovered, and the hole is saved thereby, the time consumed in drilling that hole is considered as productive time. The number of personnel in a drilling crew has no influence upon this category except to increase the total amount of time consumed during a shift in waiting upon the various elements.

Idle Time

Idle time is a delay that occurs during the shift with all types of drilling. Tables 4 and 5 of the long sash jumbos operated by 2 and

3-man crews respectively, show that although the latter crew contains an additional man less time transpired in the above delay. This ordinarily exists because a more complete standardization of the drilling procedure has been brought about since an analysis was made by Forrester & Taylor[14] and hence, in many cases, the drill crew may now drill an additional face to thereby increase their footage. This of course, tends to reduce idle time. (See Plates 6 and 7).

14. Forrester, J. D., and Taylor, J. F. A., op. cit., pp. 1-64.

Conclusions

In the foregoing analysis an attempt has been made to interpret the effect of different size crews applied to both jumbo and post-mounted drills. It must be emphasized that although the drilling procedure is basically the same today as it was at the time of introduction of the jumbos, the drilling crews have become more skilled and proficient in the use of the machines, and thus in comparing time studies made at that time to those taken recently, the above factor must be borne in mind.

As has been stated previously the original jumbo crew consisted of two men to each drill, however, it has been found, as a result of this study, that it is nearly as efficient and more economical to do without the aid of helpers. Although the helpers may directly aid in either productive or non-productive phases of drilling the effect of their absence does not materially reduce the footage drilled during a shift.

The work required per man for three men to operate two post-mounted drills is much greater than that of two men in operating one post-mounted drill, consequently the elements "erecting post" and "setting up" have been increased with a corresponding decrease in the time left available for productive drilling. However, the reader should bear in mind that in the former operation two drills are doing productive work and thus the total footage drilled in a shift is greater than that for the post-mounted drill with a 2-man crew. In the writer's opinion, if a number of post-mounted drills with 3-man crews for two posts were operated closely together and simultaneously under the most advantageous conditions, the resulting efficiency would be greater than that presented here as based on the time study statistics taken of operations where the drills were not too advantageously located.

This comparative analysis indicates that, although helpers directly aid the operation of jumbo drills in some of the categories of drilling and thereby increase the total feet drilled per shift by a jumbo unit, more economical and efficient results accrue from the overall standpoint of mining when both long sash jumbos and short sash jumbos are operated with crews which are comprised only of drillers. That is, it is concluded that it is cheaper and better mining practice to operate jumbo units without helpers.

Bibliography

1. Clarke, S. S., Mining methods, Eagle-Picher number, Engineering and Mining Journal, Vol. 144, No. 11, pp. 80-89, (Nov., 1943).

2. Clarke, S. S., Rubber-tired blitz buggies haul ore underground. Engineering & Mining Journal, Vol. 145, No. 12, pp. 88-90, (Dec., 1944).

3. Forrester, J. D., and Taylor, J. F. A., A comparative analysis of some recent mining practices in the Tri-State mining district. Missouri School of Mines & Metallurgy. Tech. Series, Vol. 16, No. 1, 1945., pp. 64.

4. Fowler, G. M., Structural control of ore deposits in the Tri-State zinc and lead district. Engineering & Mining Journal, Vol. 139, No. 9, pp. 46-51.

5. Fowler, G. M., and Lyden, J. P., The ore deposits of the Tri-State district. Amer. Inst. Min. & Met. Engrs. Trans. Vol. 102, pp. 206-251, (1932).

6. Harley, G. T., Time-study methods for mining operations, Engineering & Mining Journal, Vol. 123, pp. 722-729, (1927).

7. Truscott, S. J., Scientific management in mining, Engineering & Mining Journal, Vol. 128, pp. 133-137, (July, 1929).

8. Weidman, S., The Miami-Picher zinc-lead district, Oklahoma, Economic Geol. Vol. 28, Connecticut, 1933, pp. 82-84.

Index

VITA

Julian Alban Fuller was born in Adelaide, Australia on February 25, 1919. He came to the United States in 1926 where he received six years of elementary schooling at the Bedford Elementary School, Bedford, New York. In 1932 he went to the Truro Public School, Truro, Cornwall, England and graduated therefrom in 1938. He was immediately admitted to the Camborne School of Mines, Camborne, Cornwall, England. In 1939 he returned to the United States and entered the Missouri School of Mines at Rolla, Missouri, and graduated with a Bachelor of Science in Mining Engineering in January 1942.

In February 1942 he was employed by the Crouch Mining Company, Inc., Bauxite, Arkansas, as mining engineer and in December 1944 as assistant superintendent.

He returned to the Missouri School of Mines as Research Fellowship in Mining in July 1945 and received the degree of Master of Science in Mining Engineering in May 1946. He is a member of A.I.M.E. and Alpha Lambda Tau.